Sept 25, 1990

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RECORD OF DECISION

for the

DEPARTMENT OF THE ARMY
LOGISTICS CENTER
FORT LEWIS, WASHINGTON

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DECLARATION OF THE RECORD OF DECISION

SITE NAME AND LOCATION

Logistics Center
Fort Lewis, Pierce County, Washington

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Logistics Center operable unit, at Fort Lewis, Washington, which was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986, and to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan. This decision is based on the administrative record for the Logistics Center operable unit.

The State of Washington concurs with the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF THE SELECTED REMEDY

The selected remedy for the Logistics Center operable unit addresses the principal threats posed by the site by treating the groundwater and by flushing secondary source residual contamination. The remedy is designed to reduce exposure to the contaminated groundwater and to remediate the groundwater to levels that are protective of human health and the environment.

The major components of the selected remedy include:

- Install groundwater extraction wells capable of capturing the groundwater contaminant plume in the unconfined aquifer.

- Install on-site groundwater treatment facilities to remove contaminants from the collected groundwater.

- To expedite groundwater remediation, install groundwater extraction wells near areas of highest concentration of contamination and discharge treated groundwater upgradient of these extraction wells to facilitate flushing secondary sources from the groundwater.

- Monitor the groundwater contaminant plume and the extraction/treatment system during groundwater remediation activities to ensure that both groundwater and surface water remediation goals are achieved.

- Implement administrative and institutional controls that supplement engineering controls and minimize exposure to releases of hazardous substances during remediation.

- Investigate the lower aquifer(s) to determine the presence of contamination and to evaluate the extent of contamination, if necessary. If contamination is found, a groundwater extraction system will be installed which is capable of capturing the contaminant plume with subsequent treatment of the extracted groundwater in the on-site treatment facility. The remediation goals specified for the unconfined aquifer will also apply to any contaminated lower aquifers.

- Perform confirmation soil sampling to ensure that all remaining sources of soil contamination have been identified and characterized.

DECLARATION

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost effective. This remedy uses permanent solutions and alternative treatment technology to the maximum extent practicable, and satisfies the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element.

Because this remedy will result in hazardous substances remaining on-site in the groundwater above health-based levels for longer than five years, a review will be performed within five years after the commencement of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

Signature sheet for the foregoing Fort Lewis Logistics Center Record of Decision between the Department of the Army and U.S. Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

Lewis D. Walker

LEWIS D. WALKER
Deputy Assistant Secretary of the Army (I,L, & E)
Environment, Safety and Occupational Health

9/25/90
Date

C. A. H. Waller

LIEUTENANT GENERAL C. A. H. WALLER
Commander, I Corps and Fort Lewis

16 Sep 90
Date

Signature sheet for the foregoing Fort Lewis Logistics Center Record of Decision between the Department of the Army and the U.S. Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

Thomas P. Dunne

THOMAS P. DUNNE
Acting Regional Administrator, Region 10
U.S. Environmental Protection Agency

9-25-90
Date

EPA_Concurrence

Signature sheet for the foregoing Fort Lewis Logistics Center Record of Decision between the Department of the Army and the U.S. Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

THOMAS P. DUNNE
Acting Regional Administrator, Region 10
U.S. Environmental Protection Agency

Date

	NEARMAN	HOFER	M. KIRK	C. FINDLEY				
Dept	FFSFB HW074	FFSFB HW074	ORC	H W D				
Date	9/17/90	9/17/90	mlk					
Initial	mjn		9/17/90	9/18/90				

Signature sheet for the foregoing Fort Lewis Logistics Center Record of Decision between the Department of the Army and the U.S. Environmental Protection Agency, with concurrence by the State of Washington Department of Ecology.

For CHRISTINE GREGOIRE
Director, State of Washington Department of Ecology

9/13/90
Date

KENNETH O. EIKENBERRY
Attorney General
State of Washington

9/18/90
Date

DECISION SUMMARY

INTRODUCTION

The Fort Lewis Logistics Center was listed on the National Priorities List (NPL) in December 1989, under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

An installation-wide Federal Facilities Agreement (Agreement), Administrative Docket Nos. 1088-06-16-120 and 1089-09-23-120, between the United States Army (Army), the United States Environmental Protection Agency (EPA), and the State of Washington Department of Ecology (Ecology) became effective January 29, 1990. The Agreement establishes a procedural framework for agency coordination and a schedule for all CERCLA activities conducted at Fort Lewis.

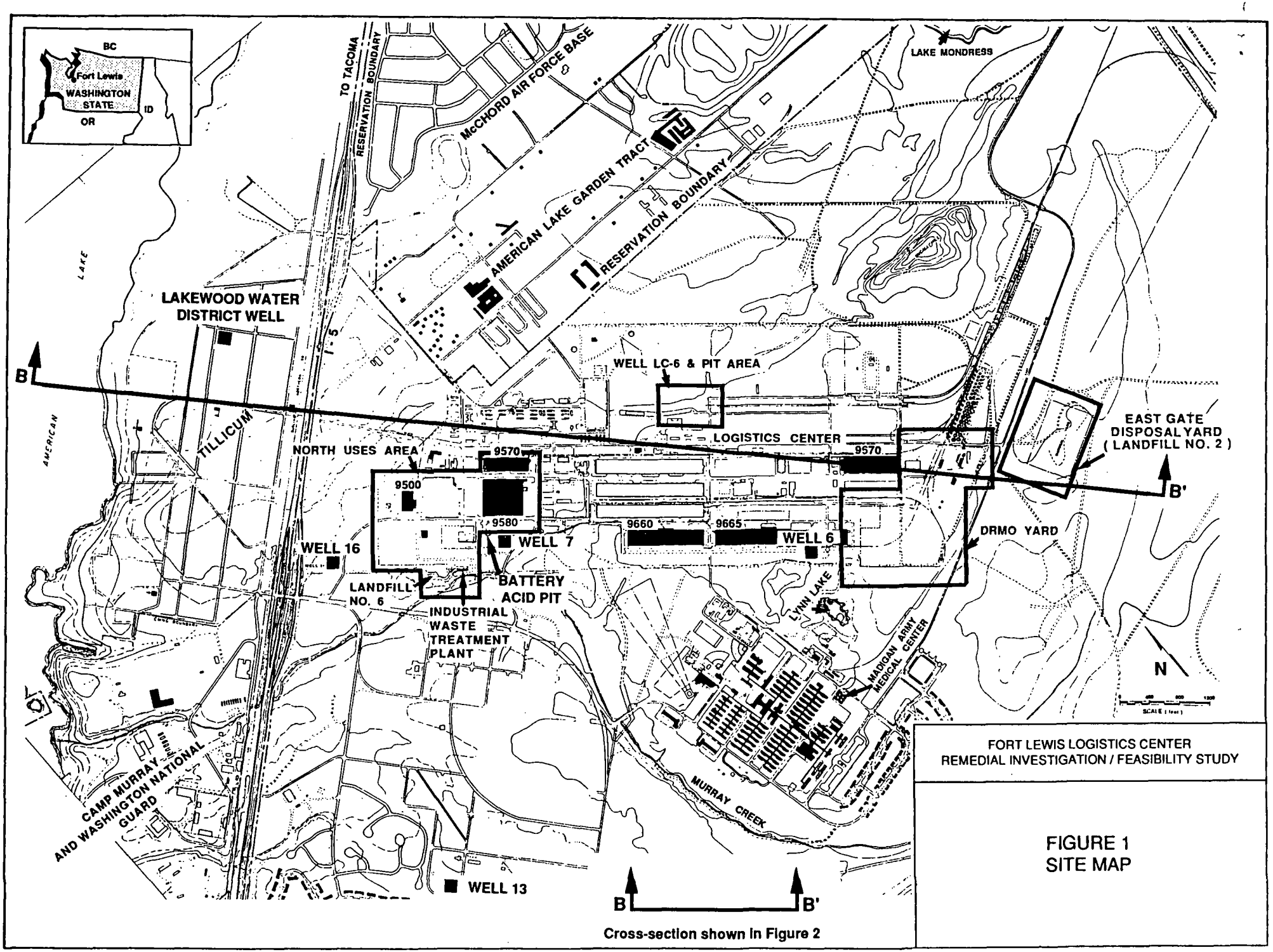
Pursuant to Executive Order 12580 (Superfund Implementation) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the Army performed a Remedial Investigation/Feasibility Study (RI/FS) for the Logistics Center. The Remedial Investigation (RI)(1988) characterized contamination in the groundwater, soil, surface water, and sediments. The Baseline Risk Assessment (1989) evaluated potential effects of the contamination on human health and the environment. The Feasibility Study (FS)(1990) evaluated alternatives for remediating contamination. In accordance with section 120(e)(2) of CERCLA, the Army will begin the remedial action within 15 months of completion of the RI/FS process.

I. SITE NAME, LOCATION, AND DESCRIPTION (Figure 1)

The Fort Lewis Logistics Center is located in Pierce County, Washington, approximately 11 miles south - southeast of Tacoma and approximately 17 miles east - northeast of Olympia (Figure 1). The Logistics Center occupies approximately 650 acres of the Fort Lewis military reservation, located in T 19 N, R 2 E, Sections 21, 22, 26, and 27. It is bounded to the northwest by Interstate 5, to the southwest by the Fort Lewis Madigan Army Medical Center, to the north by the American Lake Gardens Tract, and to the east by outlying areas of the Fort Lewis installation.

The Logistics Center is an industrial complex comprised of warehouses, motor pools, maintenance facilities, and an equipment disposal yard. The following four potential source areas were investigated as part of the RI:

- East Gate Disposal Yard (includes Landfill No. 2);
- Defense Reutilization and Marketing Office (DRMO) Yard (previously known as DPDO Yard);
- North Uses Area (includes Landfill No. 6, Industrial Wastewater Treatment Plant [IWTP], and Battery Acid Pit); and
- Well LC-6 and Pit Area.



FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY

FIGURE 1
SITE MAP

Approximately 85,000 residents reside within a three-mile radius of the Logistics Center in the surrounding communities of Fort Lewis, Tillicum, American Lake Gardens Tract, Lakewood, and McChord Air Force Base. Tillicum is a mixed residential and commercial area without a major industry. The commercial use consists mainly of restaurants, gas stations, and convenience stores. The American Lake Gardens Tract is predominantly a residential area. Lakewood is a mixed residential and commercial area.

Drinking water for Tillicum and American Lake Gardens Tract is supplied by the Lakewood Water District. The nearest Lakewood Water District well is located within one mile northwest of the Logistics Center and draws water from a depth of approximately 480 feet from within the Puyallup Formation aquifer. Fort Lewis receives its drinking water primarily from Sequalitchew Springs, which is located within one mile southwest of the Logistics Center and adjacent to Sequalitchew Lake. Two emergency backup drinking water wells (Wells 13 and 16) are located within one mile of the Logistics Center. Each well draws water from several aquifers located beneath the contaminated unconfined aquifer. A third drinking water well (Well 7), which is not used, is scheduled for abandonment in accordance with the Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).

The nearest surface water bodies are American Lake, Lynn Lake, Mondress Lake, and Murray Creek, all of which are located within one mile of the Logistics Center. The Logistics Center is located within five miles of the Puget Sound.

II. SITE HISTORY AND ENFORCEMENT ACTIVITIES

The Logistics Center, formerly called the Mount Rainier Ordnance Depot, was built in the early 1940s. The Logistics Center is used for storing supplies and providing maintenance of military equipment and vehicles. The primary contaminant, trichloroethylene (TCE), is a common industrial and commercial solvent and degreaser, and was used for maintenance activities until the mid-1970s. The waste TCE, which was often combined with waste oil, was disposed of at several areas within the Logistics Center.

In 1985, the Army identified traces of TCE in several monitoring wells installed in the unconfined aquifer beneath the Logistics Center. A limited site investigation was performed in 1986 under the Department of Defense Installation Restoration Program (IRP). During 1986 and 1987, the EPA performed a groundwater investigation in and near Tillicum and found that groundwater contamination in Tillicum appeared to originate from the Logistics Center. As a result, the Army agreed to study the groundwater plume off the installation as part of the Logistics Center RI. The Army began the RI in 1987, which included a field investigation to determine contamination in soil, groundwater, surface water, and sediments. In 1988, the RI was modified to include study of the horizontal extent of the off-post groundwater plume.

Drinking water for most residents in the Tillicum area is supplied by the Lakewood Water District. However, during the RI, the Army identified several residents using private drinking water wells. The Army subsequently sampled these wells and connected residents with contaminated wells to the Lakewood Water District.

A. Source Areas

During the 1986 IRP site investigation, four potential areas of contamination were identified within the Logistics Center where maintenance and disposal activities reportedly occurred. Minimal historical information for each potential source area exists. These potential source areas were investigated as part of the RI. They were defined as the East Gate Disposal Yard, the DRMO Yard, the North Uses Area, and Well LC-6 and Pit Area (Figure 1).

1. East Gate Disposal Yard

The East Gate Disposal Yard was used between 1946 and 1960 as a disposal site for waste generated by the Mount Rainier Ordnance Depot. Interpretation of aerial photographs indicated several trenches were excavated in the yard. The trenches reportedly were used for the disposal of waste TCE and petroleum, oils, and lubricants (POL) from equipment cleaning and degreasing activities. The trenches were subsequently backfilled and are not currently visible.

2. North Uses Area

The North Uses Area consists of Landfill No. 6, the Industrial Wastewater Treatment Plant (IWTP), and the Battery Acid Pit.

The IWTP began operating in 1954. The facility predominantly receives storm water runoff from nearby maintenance facilities. Effluent from the IWTP is discharged to a no-outlet evaporation/percolation lagoon. Sludges and sediments from the lagoon are currently disposed of in the on-post municipal landfill, which is not located at the Logistics Center. From 1954 to the mid-1970s, sediment and sludges from the IWTP's evaporation/percolation lagoon were disposed of in Landfill No. 6.

From 1971 to 1976, electrolyte solutions from batteries were discharged into the Battery Acid Pit, which contained crushed limestone. While it is not known how many varieties of batteries were drained at the Battery Acid Pit, it is known that the majority were vehicle batteries containing lead-acid electrolyte.

3. Well LC-6 and Pit Area

The Well LC-6 and Pit Area is comprised of an abandoned POL pit in the vicinity of Well LC-6. The pit area consisted of a storage/disposal pit which reportedly contained a storage tank. However, subsequent investigations revealed no evidence of a storage tank in this area. The pit appears on aerial photographs dated 1951, and may have been a disposal site for waste oil and solvent from nearby vehicle storage areas.

4. DRMO Yard

The DRMO Yard is used currently as a general use temporary storage area. Stored materials include equipment containing residual polychlorinated biphenyls (PCBs). In the past, unknown quantities of stored materials included drums containing waste TCE and equipment containing PCBs.

III. COMMUNITY RELATIONS

The public was first notified of the Logistics Center groundwater contamination in January 1985. At that time, the Army announced that it had discovered TCE in new monitoring wells installed at the Logistics Center. This announcement was published in several area newspapers.

A. Community Relations during the RI/FS

In August 1986, following completion of the limited site investigation, several newspapers published articles announcing the results of the investigation. It was reported that TCE-contaminated groundwater originating from the Logistics Center was a potential threat to the Lakewood Water District well located in Tillicum.

In 1987, a community relations plan (CRP) was prepared in accordance with CERCLA, as amended by SARA. The CRP included establishing information repositories and communication pathways to disseminate information. Information repositories were established at the following four locations:

Pierce County Library - Lakewood Branch;
Pierce County Library - Tillicum Branch;
Tacoma Pierce County Health Department; and
Fort Lewis - Environmental Division.

Also, in accordance with section 113 of CERCLA, an administrative record was established to provide the basis for selection of the remedial action. The administrative record is available for public review at the Fort Lewis Environmental Division and the Lakewood Branch of the Pierce County Library.

During the RI/FS, the Army issued three fact sheets and three press releases. In March 1987, the first fact sheet announced the beginning of the RI/FS. The second fact sheet was released in February 1988 when the RI/FS was modified to include Tillicum. A third fact sheet, released in February 1989, discussed the risk assessment. After releasing the second and third fact sheets, the Army held public workshops to present information and to answer questions. Both workshops were held at the Tillicum/American Lake Gardens Community Service Center and coincided with regular monthly public meetings held at the Center. Between 20 to 40 people attended each workshop.

In January 1990, two newspaper articles were published. The first article announced the listing of the Logistics Center to the NPL. The second article announced the signing of the Federal Facilities Agreement.

B. Community Relations to support selection of remedy

In accordance with sections 117 and 113(k)(2)(B) of CERCLA, the public was given the opportunity to participate in the remedy selection process. The proposed plan, which summarized the alternatives evaluated and presented the preferred alternative, was mailed to approximately 250 interested parties in June 1990. The Army provided public notice through a display ad in the Tacoma News Tribune and the Lakewood Journal to explain the proposed plan, list the public comment period, and announce the public meeting. A news release was also provided to the local news media which resulted in news coverage by four local newspapers and two radio stations.

A 45-day public comment period was held from June 5 to July 19, 1990. No requests for extensions and no written comments were received during the comment period. Approximately 30 people attended an open house/public meeting, which was held on June 28, 1990 in Tillicum. Responses to comments received at the public meeting are included in the attached Responsiveness Summary.

A fact sheet summarizing the Record of Decision (ROD), public comments, and the Army's response will be mailed to interested parties on the mailing list after the ROD is signed. Copies of the ROD and the Responsiveness Summary will be placed in the administrative record and in the information repositories.

IV. SCOPE AND ROLE OF RESPONSE ACTION WITHIN SITE STRATEGY

The selected remedy for final action is intended to address all the concerns originating from the contamination at the Logistics Center, including the principal threat of volatile organic compound (VOC) contamination in the unconfined aquifer.

The primary purpose of the selected remedy is to restore the unconfined aquifer to Class I, or drinking water, status. In addition, the selected remedy establishes cleanup standards for the remediation of all aquifers exhibiting contamination from the Logistics Center. The Army will perform additional field work in Fall 1990 to determine and characterize contamination in the lower aquifers. If contamination originating from the Logistics Center is found, remediation (cleanup) goals specified herein will apply to the affected aquifer(s).

During the RI, contamination was discovered in private drinking water wells that draw water from the

unconfined aquifer. The immediate threat to human health was eliminated when the Army connected well owners to the Lakewood Water District. However, the private drinking water wells were not abandoned. No administrative or institutional mechanism is available that requires the abandonment of private residential wells due to chemical contamination. Through community relation activities, the Army continues to notify the residents that the wells should not be used for drinking water. The selected remedy includes the use of administrative controls to regulate construction of new wells within the contaminated unconfined aquifer and to discourage use of existing contaminated wells.

To aid in the design of the on-site treatment system, interim groundwater and surface water sampling will continue until the treatment facility is constructed. Once treatment begins, a long-term monitoring program will be implemented to evaluate performance of the extraction/treatment system and compliance with remediation goals.

Potential source areas within the Logistics Center were sampled during the RI/FS to determine if soil contamination was a threat to public health and the environment. While analytical results indicate that the soil does not pose a direct threat to human health, it may act as a source of contamination to the groundwater. The efficacy of the groundwater remediation will be monitored quarterly during remedial action. In the event that residual contamination in the soil adversely impacts the ability to remediate groundwater, the need for soil treatment will be reevaluated.

Soil sampling results from the RI indicate that no sources of soil contamination at the Logistics Center present an unacceptable risk to human health or the environment. However, subsequent field screening at the DRMO yard found previously unidentified areas of potential PCB soil contamination. As part of the selected remedy, the Army will conduct confirmation soil sampling in all four potential source areas, including the DRMO yard, to ensure that all soil contamination within the Logistics Center has been identified and characterized. Based on the results of the confirmation sampling, a prompt determination will be made, pursuant to the procedures outlined in the Federal Facility Agreement, regarding the need for a response action. The Army will notify the public of the results from the confirmation soil sampling. Any necessary response action will be undertaken by the Army, in consultation with EPA and Ecology, pursuant to the NCP Part 300.

V. DOCUMENTATION OF SIGNIFICANT CHANGES

The proposed plan originally discussed a waste management area to address a potential risk associated with residual soil contamination within the Logistics Center. However, based on acceptable exposure levels outlined in the final NCP, the residual soil contamination levels are within the acceptable exposure levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. Therefore, there is no waste management area and the remediation goals will be attained throughout the contaminated plume.

VI. SUMMARY OF SITE CHARACTERISTICS

Analyses of the soil, groundwater, surface water, and sediments indicate that groundwater contamination is the principal threat at the Logistics Center site. The primary contaminants found in the groundwater are trichloroethylene (TCE) and cis 1,2 - dichloroethylene (DCE).

Solvents that include TCE, tetrachloroethylene (PCE), and 1,1,1 - trichloroethane (TCA) were used for maintenance activities at the Logistics Center. TCE was used until the mid-1970s. An accurate estimate of the amount of TCE disposed of cannot be made because there is minimal recorded disposal information before the 1970s. The source of DCE contamination is not known, as DCE was not used at the Logistics Center. DCE was possibly an impurity of the TCE solvent and/or is the degradation product of TCE.

The potentially exposed populations include the residents of Tillicum and the American Lake Gardens Tract that still have functioning contaminated private wells. These residents are now connected to an alternate water supply, but the wells have not been abandoned. In addition, potential exposure may occur if new private wells were to be installed into the unconfined aquifer. If the contamination migrates to the deeper aquifers, it could potentially affect the water supply for approximately 85,000 people in the surrounding communities of Fort Lewis, Lakewood, Tillicum, and American Lake Gardens Tract.

The following discussion summarizes data from the sampling and analyses performed as part of the RI.

A. Groundwater Contamination

The Logistics Center is on an extensive upland glacial drift plain which occupies much of central Pierce County (Figure 2, Table 1). The geologic investigations demonstrate that the hydrostratigraphy of the area is extremely diverse and complex. There are numerous different geologic units in the 300 feet beneath the Logistics Center. These units vary both horizontally and vertically making hydrological interpretation very difficult. Generally, the geology beneath the Logistics Center consists of sand and gravel deposits with till layers (Vashon Drift) overlying a finer - grained, nonglacial deposit (Kitsap Formation). The Vashon Drift is mostly permeable and contains the unconfined aquifer beneath the site. The base of the aquifer is the Kitsap formation, which separates the unconfined aquifer from the Salmon Springs aquifer, which is between 100 to 200 feet below the surface. In addition, the Salmon Springs overlies the Puyallup Formation, which is between 250 to 450 feet below the surface. The unconfined aquifer is continuous across the site; the water table is between 7 to 35 feet below the surface.

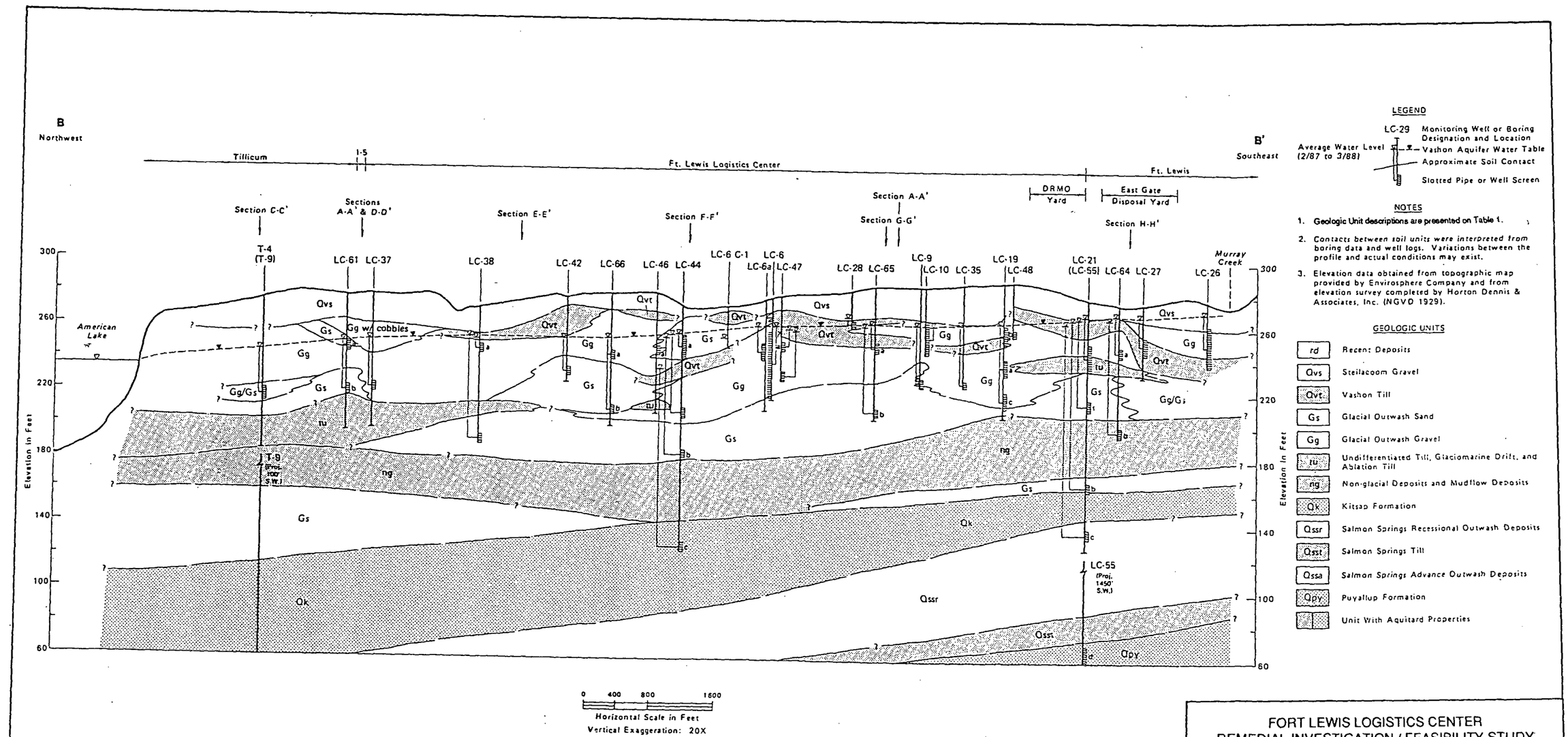
Groundwater beneath the Logistics Center is recharged by groundwater inflow from the southeast, and from infiltration of precipitation through the permeable soils. The water table gradient (slope) is to the north - northwest across the Logistics Center and is approximately 10 feet per mile. Groundwater velocities range from 0.03 to 26 feet per day, with a median velocity of 1.5 feet per day. Aquifer transmissivity ranges from 14,000 to 20,000 gallons per day per foot.

During the RI, 96 pre-existing wells and 33 new wells were sampled for TCE and DCE. Six wells were sampled for Hazardous Substance List (HSL) compounds. Five of the new wells were installed at depths of 150, 200, 300 feet in the lower aquifers (the aquifers below the unconfined aquifer). Table 2 summarizes the groundwater sampling results from the RI and lists available MCL/MCLGs for contaminants found.

VOC contamination has been found in the groundwater beneath and northwest (downgradient) of the Logistics Center. The VOCs detected in the groundwater were TCE, DCE, PCE, and TCA. TCE and DCE exceeded EPA's Maximum Contaminant Levels (MCLs) for drinking water. Vinyl chloride, a degradation product of TCE, was not detected in the wells sampled. PCE was detected slightly above its MCL of 5 ug/l (micrograms per liter) in one sample for one sampling event. TCA was detected below its MCL of 200 ug/l. TCE ranged in concentrations from less than 0.1 ug/l to 2400 ug/l, with an average concentration of 325 ug/l. DCE ranged in concentrations from less than 0.15 ug/l to 130 ug/l, with an average concentration of 24 ug/l. The highest contamination levels in the unconfined aquifer appear to be between 16 to 37 feet below the ground surface.

In the Salmon Springs aquifer, six wells (Figure 3: T-9, T-9e; LC-41 d,e; LC-55 d,e) were sampled for contamination. One well (LC-41d at a 200 foot depth) showed a maximum TCE level of 143 ug/l. No contamination was found in the other five wells.

In general, the contaminant plume (the area of groundwater contamination) in the unconfined aquifer migrates from the southeast to the northwest, from the East Gate Disposal Yard, under the Logistics Center, Tillicum and the southwest corner of the American Lake Gardens Tract. Figure 3 shows the horizontal extent of the groundwater plume in the unconfined Vashon Drift aquifer. The vertical cross section of TCE contamination in the unconfined aquifer (defined by the 5 ug/l TCE concentration limit) is fairly constant along the path of the groundwater plume. The contaminated plume is between 3,000 to 4,000 feet wide with a contaminated thickness of between 60 to 80 feet.



LEGEND

LC-29 Monitoring Well or Boring Designation and Location

Average Water Level (2/87 to 3/88) — Vashon Aquifer Water Table

Approximate Soil Contact

Slotted Pipe or Well Screen

NOTES

1. Geologic Unit descriptions are presented on Table 1.
2. *Contacts between soil units were interpreted from* boring data and well logs. Variations between the profile and actual conditions may exist.
3. Elevation data obtained from topographic map provided by Envirosphere Company and from elevation survey completed by Horton Dennis & Associates, Inc. (NGVD 1929).

GEOLOGIC UNITS

rd	Recent Deposits
Qvs	Steilacoom Gravel
Qvt	Vashon Till
Gs	Glacial Outwash Sand
Gg	Glacial Outwash Gravel
tu	Undifferentiated Till, Glaciomarine Drift, and Ablation Till
ng	Non-glacial Deposits and Mudflow Deposits
Qk	Kitsap Formation
Qssr	Salmon Springs Recessional Outwash Deposits
Qsst	Salmon Springs Till
Qssa	Salmon Springs Advance Outwash Deposits
Qpy	Puyallup Formation
	Unit With Aquitard Properties

Note: Refer to Figure 1 for cross-section location.

FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY

FIGURE 2
PRELIMINARY HYDROGEOLOGIC PROFILE

Table 1 Description of Geologic Units

GEOLOGIC/ STRATIGRAPHIC UNIT	SITE GEOLOGIC NAME		DESCRIPTION	Approximate Depth to Top of Unit, Ft.	Approximate Thickness, Ft.	SITE HYDROGEOLOGIC DESIGNATION
Recent	Recent Deposits	rd	Predominantly alluvial silt, sand, and gravel with lesser amounts of organic depression fillings	0, locally present	0-10	aquifer where saturated
Vashon & Stade-Fraser Glaciation	Steilacoom Gravel	Qvs	Open-work coarse gravel with abundant cobbles	0-10	20-40	Vashon Drift/post-Kitsap Aquifer
	Vashon Till	Qvt	Very dense lodgement till: gravelly, clayey sandy silt; and loose ablation till: gravelly, clayey, sandy silt.	3-50, locally absent	2-20	(Qvt-aquitard)
Vashon & pre-Vashon outwash	Glacial Outwash Sand	Gs	Predominantly stratified fine, medium, and course sand; interbeds of sandy gravel lenses of silt	5-125 locally inter bedded	2-100	
	Glacial outwash Gravel	Gg	Predonimamtly sandy gravel with lenses of gravelly sand and silty gravel	5-130 locally inter bedded	2-100	
pre-Vashon & post-Kitsap	Undifferentiated Till	tu	Lodgement till, glaciomarine drift (?), glaciolacustrine deposits, and lesser amounts of ablation till: predominantly very dense to hard, sandy silt and clayey silt	30-90, locally absent	2-35	(tu-aquitard)
	Non-glacial Deposits	ng	Alluvial sand and gravel; and mudflow deposits; gravel and sand in a matrix of clay and silt	70-140, locally absent	10-40	(ng-aquitard, in places
Olympia Interglacial	Kitsap Formation	Qk	Non-glacial deposits of silt, sand, and clay; with scattered ash, wood and peat	110-170	10-70	Kitsap Aquitard
Salmon Springs Glaciation	Salmon Springs Recessional Outwash	Qssr	Stratified sand and gravel with silt and clay lenses	135-225, locally absent	20-60	Salmon Springs Recessional Aquifer
	Salmon Springs Till	Qsst	Very dense, heterogeneous mixture of gravel, sand, clay, and silt	150-280	5-20	Salmon Springs Till Aquitard
	Salmon Springs Advance Outwash	Qssa	Stratified sand and gravel with silt and clay lenses	230-300, locally absent	10-80	Salmon Springs Advance Aquifer
Puyallup Interglacial	Puyallup Formation	Qpy	Mudflows, ash, and alluvial deposits	210-320	up to 135	Puyallup Aquitard
Stuck Glacial	Stuck Drift	Qst	Till, lacustrine silt and fine sand, glaciofluvial sand and gravel	>320	50-100	Stuck Drift Aquifer

TABLE 2A

Fort Lewis Logistics Center
Groundwater Sampling Results
Total (unfiltered)

Inorganics Parameter	Upgradient Range of 1/ Concentration (ug/l)	Downgradient Frequency 2/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 3/ (ug/l)	MCL 4/ (ug/l)
Aluminum	4,800-15,600	6/6	521-7,050	2,819	-	
Antimony	<7	1/13	16	16	3-10	
Arsenic	<5	7/13	2.0-14	5.2	3.2	50
Barium	50-70	12/13	9-217	63.8	2.2	1000
Beryllium	<3	0/13	-	-	1-2.2	
Cadmium	<5	5/13	1.1-6.0	3.8	1-4.1	10
Calcium	13,400-14,000	6/6	9,930-18,400	14,421	-	
Chromium	<10	11/13	1.4-34	11.5	10	50
Cobalt	20	2/6	10-16	13	8.5-10	
Copper	10-12	11/13	11.4-42	28.2	12-17	
Iron	4,400-19,100	13/13	581-25,900	6,186	-	
Lead	4.4-9.6	9/13	2.6-28	10.4	0.8-2.2	50
Magnesium	4,600-7,300	6/6	3,630-9,030	6,482	-	
Manganese	140-460	13/13	7-4,000	547	-	
Mercury	<0.2	5/13	-	1.9	0.2	2
Nickel	<30	8/13	16-100	52	16-21	
Potassium	1,200-2,100	5/6	910-1,900	1,382	840	
Selenium	<5	0/13	-	-	0.8-5	
Silver	<10-30	2/13	2.4-5.6	4	0.6-1	50
Sodium	4,900-6,000	13/13	4,560-56,000	16,737	-	
Thallium	<3	0/13	-	-	1.7-10	
Vanadium	<20	1/6	18	18	11-12	
Zinc	<20-39	13/13	7-210	75	-	
Cyanide	<5	0/6	-	-	10	

1/ preliminary results

2/ Frequency of Detection=number of detections/number of samples analyzed

3/ Range of DLs=range of detection limits

4/ MCL=maximum contaminant level

TABLE 2B

Fort Lewis Logistics Center
Groundwater Sampling Results
Total (unfiltered)

Volatiles Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)	MCL 3/ (ug/l)
Chloromethane	0/6	-	-	10-50	
Bromomethane	0/6	-	-	10-50	
Vinyl Chloride	0/6	-	-	10-50	
Chloroethane	0/6	-	-	10-50	
Methylene Chloride	0/2	-	-	25-50	
Acetone	0/4	-	-	10-100	
Carbon Disulfide	0/6	-	-	5-25	
1,1-Dichloroethylene ((DCE)	0/6	-	-	5-25	
1,1-Dichloroethane (DCA)	0/6	-	-	5-25	
1,2-Dichloroethylene (DCE)	298/502	0.1-130	24	0.10-1.2	70p 3/
Chloroform	0/6	-	-	5-25	
1,2-Dichloroethane (DCA)	0/6	-	-	5-25	
2-Butanone	0/6	-	-	10-50	
1,1,1-Trichloroethane (TCA)	1/6	1	1	5	100
Carbon Tetrachloride	0/6	-	-	5-25	
Vinyl Acetate	0/6	-	-	10-50	
Bromodichloromethane	0/6	-	-	5-25	
1,2-Dichloropropane	0/6	-	-	5-25	
cis-1,3-Dichloropropene	0/6	-	-	5-25	
Trichloroethylene (TCE)	401/503	0.1-2400	325	0.1-0.15	5
Dibromochloromethane	0/6	-	-	5-25	
1,1,2-Trichloroethane	0/6	-	-	5-25	
Benzene	0/6	-	-	5-25	
Trans-1,3-Dichloropropene	0/6	-	-	5-25	
Bromoform	0/6	-	-	5-25	
4-Methyl-2-Pentanone	0/6	-	-	10-50	
2-Hexanone	0/6	-	-	10-50	
Tetrachloroethylene (PCE)	1/6	6	6	5-25	5p 3/
Toluene	0/6	-	-	5-25	
1,1,2,2-Tetrachloroethane	0/6	-	-	5-25	
Chlorobenzene	0/6	-	-	5-25	
Ethylbenzene	0/6	-	-	5-25	
Styrene	0/6	-	-	5-25	
Xylenes Total	0/6	-	-	5-25	
2-chloroethyl vinyl ether	0/6	-	-	10-50	

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

3/ MCL=maximum contaminant level

TABLE 2C

Fort Lewis Logistics Center
Groundwater Sampling Results
Total (unfiltered)

Semivolatiles Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)
Phenol	0/6	-	-	10
bis(2-Chloroethyl)Ether	0/6	-	-	10
2-Chlorophenol	0/6	-	-	10
1,3-Dichlorobenzene	0/6	-	-	10
1,4-Dichlorobenzene	0/6	-	-	10
Benzyl Alcohol	0/6	-	-	10
1,2-Dichlorobenzene	0/6	-	-	10
2-Methylphenol	0/6	-	-	10
bis(2-Choloroisopropyl)Ether	0/6	-	-	10
4-Methylphenol	0/6	-	-	10
N-Nitroso-Di-n-Dipropylamine	0/6	-	-	10
Hexachloroethane	0/6	-	-	10
Nitrobenzene	0/6	-	-	10
Isophorone	0/6	-	-	10
2-Nitrophenol	0/6	-	-	10
2,4-Dimethylphenol	0/6	-	-	50
Benzoic Acid	0/6	-	-	10
bis(2-Chloroethoxy)Methane	0/6	-	-	10
2,4-Dichlorophenol	0/6	-	-	10
1,2,4-Trichlorobenzene	0/6	-	-	10
Naphthalene	0/6	-	-	10
4-Chloroaniline	0/6	-	-	10
Hexachlorobutadiene	0/6	-	-	10
4-Chloro-3-Methylphenol	0/6	-	-	10
2-Methylnaphthalene	0/6	-	-	10
Hexachlorocyclopentadiene	0/6	-	-	10
2,4,6-Trichlorophenol	0/6	-	-	10
2,4,5-Trichlorophenol	0/6	-	-	50
2-Chloronaphthalene	0/6	-	-	10
2-Nitroaniline	0/6	-	-	50

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

TABLE 2C (continued)

Fort Lewis Logistics Center
Groundwater Sampling Results
Total (unfiltered)

Semivolatiles Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)
Dimethyl Phthalate	0/6	-	-	10
Acenaphthylene	0/6	-	-	10
2,6-Dinitrotoluene	0/6	-	-	10
3-Nitroaniline	0/6	-	-	50
Acenaphthene	0/6	-	-	10
2,4-Dinitrophenol	0/6	-	-	50
4-Nitrophenol	0/6	-	-	50
Dibenzofuran	0/6	-	-	10
2,4-Dinitrotoluene	0/6	-	-	10
Diethylphthalate	0/6	-	-	10
4-Chlorophenyl-phenyl Ether	0/6	-	-	10
Fluorene	0/6	-	-	10
4-Nitroaniline	0/6	-	-	50
4,6-Dinitro-2-Methylphenol	0/6	-	-	50
N-Nitrosodiphenylamine	0/6	-	-	10
4-Bromophenyl-phenylether	0/6	-	-	10
Hexachlorobenzene	0/6	-	-	10
Pentachlorophenol	0/6	-	-	50
Phenanthrene	0/6	-	-	10
Anthracene	0/6	-	-	10
Di-n-Butylphthalate	0/6	-	-	10
Fluoranthene	0/6	-	-	10
Pyrene	0/6	-	-	10
Butylbenzylphthalate	0/6	-	-	10
3,3'-Dichlorobenzidine	0/6	-	-	20
Benzo(a)Anthracene	0/6	-	-	10
Chrysene	0/6	-	-	10
bis(2-Ethylhexyl)Phthalate	0/6	-	-	10
Di-n-Octyl Phthalate	0/6	-	-	10
Benzo(b)Fluoranthene	0/6	-	-	10
Benzo(k)Fluoranthene	0/6	-	-	10
Benzo(a)Pyrene	0/6	-	-	10
Indeno(1,2,3-cd)Pyrene	0/6	-	-	10
Dibenz(a,h)Anthracene	0/6	-	-	10
Benzo(g,h,i)Perylene	0/6	-	-	10

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

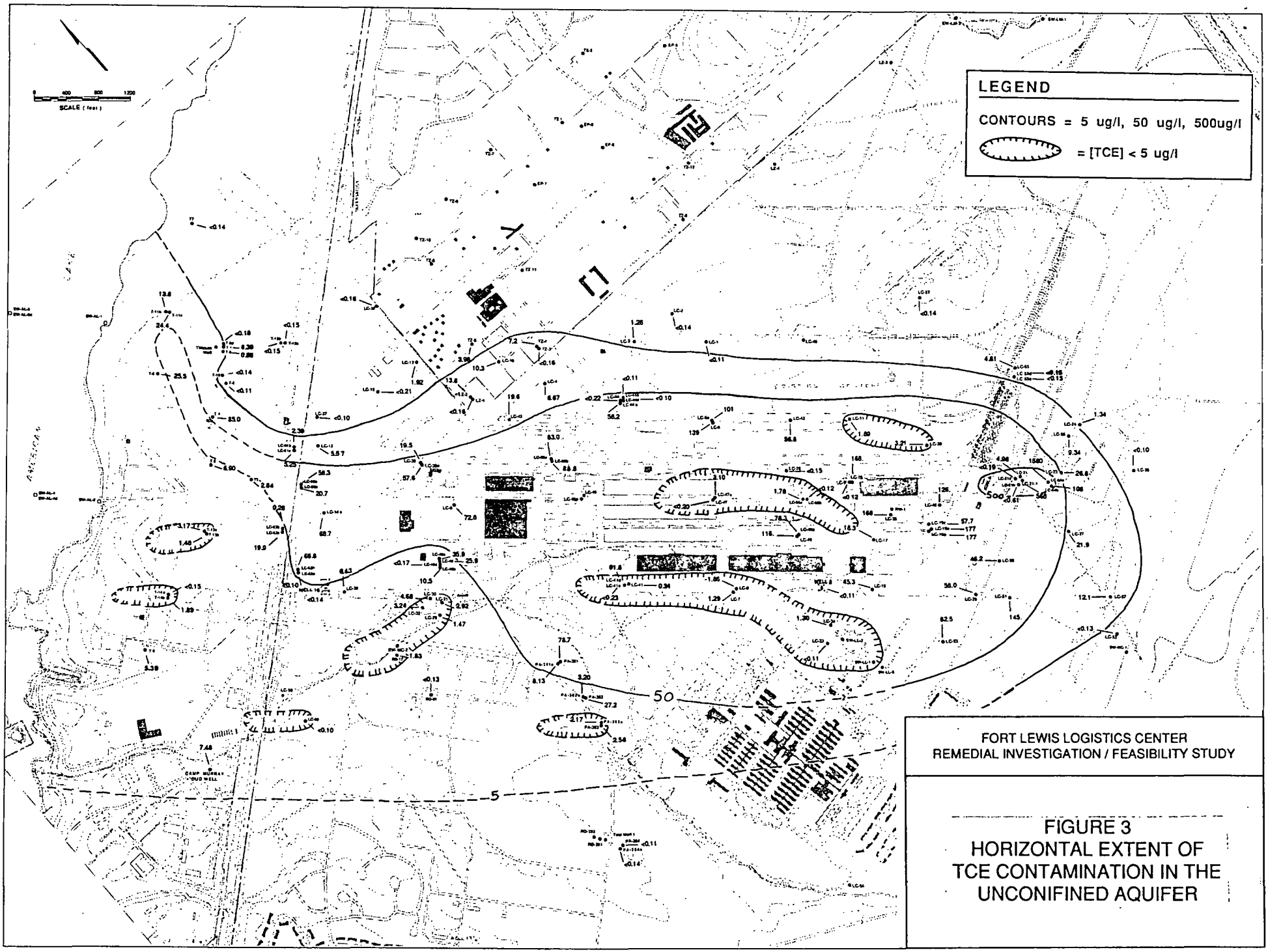
TABLE 2D

Fort Lewis Logistics Center
Groundwater Sampling Results
Total (unfiltered)

Pesticides/PCBs Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)
alpha-BHC	0/6	-	-	0.01-0.05
beta-BHC	0/6	-	-	0.01-0.05
delta-BHC	0/6	-	-	0.01-0.05
gamma-BHC(Lindane)	0/6	-	-	0.01-0.05
Heptachlor	0/6	-	-	0.01-0.05
Aldrin	0/6	-	-	0.01-0.05
Heptachlor epoxide	0/6	-	-	0.01-0.05
Endosulfan I	0/6	-	-	0.01-0.05
Dieldrin	0/6	-	-	0.02-0.10
4,4'-DDE	0/6	-	-	0.02-0.10
Endrin	0/6	-	-	0.02-0.10
Endosulfan II	0/6	-	-	0.02-0.10
4,4'-DDD	0/6	-	-	0.02-0.10
Endosulfan sulfate	0/6	-	-	0.02-0.10
4,4'-DDT	0/6	-	-	0.02-0.10
Methoxychlor	0/6	-	-	0.10-0.50
Endrin ketone	0/6	-	-	0.02-0.10
Chlordane	0/6	-	-	0.10-0.50
Toxaphene	0/6	-	-	0.20-1.0
Aroclor-1016	0/6	-	-	0.10-0.50
Aroclor-1221	0/6	-	-	0.10-0.50
Aroclor-1232	0/6	-	-	0.10-0.50
Aroclor-1242	0/4	-	-	0.10-0.50
Aroclor-1248	0/6	-	-	0.10-0.50
Aroclor-1254	0/6	-	-	0.2-1.0
Aroclor-1260	0/6	-	-	0.2-1.0

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits


LEGEND
CONTOURS = 5 ug/l, 50 ug/l, 500ug/l
= [TCE] < 5 ug/l
SCALE (feet)
0 400 800 1200
50
5
FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIGURE 3
HORIZONTAL EXTENT OF
TCE CONTAMINATION IN THE
UNCONIFINED AQUIFER

Based on groundwater contours, TCE contamination from groundwater appears to discharge into American Lake at levels slightly above 5 ug/l. Subsequent sampling found that TCE and DCE levels were not elevated in the surface water or sediments of American Lake. Results from the surface water sampling are discussed below.

B. Surface Water and Sediment Contamination

Surface waters and sediments that could be affected by contamination from the Logistics Center were sampled. Surface water and sediment samples were collected from American Lake, Lynn Lake, Murray Creek, and Lake Mondress. Based on groundwater sampling results, surface water and bottom sediment samples were tested for TCE and DCE. Table 3 summarizes the results of surface water and sediment sampling and compares levels found with federal Ambient Water Quality Criteria (AWQC). Although, levels in Lynn Lake and Murray Creek exceeded AWQC for drinking water and drinking water/aquatic organisms, neither surface water body is used as a drinking water source. Therefore, comparison against AWQC for ingestion of aquatic organisms is appropriate.

C. Soil Contamination

A soil gas survey was performed as part of the RI in those areas where TCE was historically stored, disposed, or used as part of maintenance operations. These potential sources areas are the East Gate Disposal Yard, the North Uses Area, Well LC-6 and Pit Area, and the DRMO Yard. The soil gas samples were analyzed for TCE, DCE, TCA, PCE, benzene, and toluene. The analytical results of the soil gas survey were used to establish locations for soil borings in areas with the highest potential for contamination. Figure 4A, 4B, 4C identify the locations of the soil gas survey and the soil borings. The maximum soil gas measurements for TCE and DCE were found in the East Gate Disposal Yard, and for PCE and TCA in the North Uses Area and DRMO Yard, respectively. Benzene and toluene were detected in soil gas in the North Uses Area.

A total of 25 soil borings were drilled throughout the potential source areas. All soil samples were analyzed for TCE and DCE. A minimum of one boring per source area was analyzed for compounds on the HSL. Refer to Table 4 for a summary of the boring analytical results.

The primary contaminant, TCE, was disposed in various locations at the Logistics Center, until its use was discontinued in the mid-1970s. Volatilization is the major mechanism for the release of TCE from surface soils. Once volatilized, the dominant fate of TCE in the atmosphere is rapid photooxidation in the troposphere; the atmospheric half-life is estimated to be 6.8 days. The Logistics Center soils generally consist of a sequence of sand and gravel and finer-grained unconsolidated sediments. In addition, because of continued construction at the Logistics Center, fill was placed at scattered locations. Based on the soil organic matter partition coefficient (K_{oc} = 126), TCE will readily leach through soils, although migration would be moderately retarded due to adsorption to soil organic matter. Based on field observations during the installation of wells, the soil at the Logistics Center does not appear to have significant total organic content. Thus, the adsorption of TCE is not expected to occur at the Logistics Center.

Similarly, volatilization is the major mechanism for the release of DCE from surface soils. Photooxidation of DCE in the troposphere is estimated to be less than one day. The low soil organic matter partition coefficient (K_{oc} = 59) of DCE indicates limited adsorption of this chemical by organic matter in soils. Thus, relatively rapid migration of DCE through the soil is expected to occur.

Because of the chemical characteristics of TCE and DCE and the historical information that disposal activities ceased over 15 years ago, it is hypothesized that the TCE and DCE readily volatilized into the troposphere or rapidly migrated through the soil into the groundwater with limited adsorption onto the soil organic fraction.

TABLE 3

Fort Lewis Logistics Center
Surface Water Sampling Results

Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)	Ambient Water Quality Criteria (ug/l)		
					Drinking Water 3/ and Aquatic Organisms	Aquatic Organisms	Drinking 3/ Water only
TCE	27/49	0.12-46	5.3	0.1-0.2	2.7	80.7	2.8
DCE	16/49	0.1-23	4.1	0.1-0.2	-	-	-

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

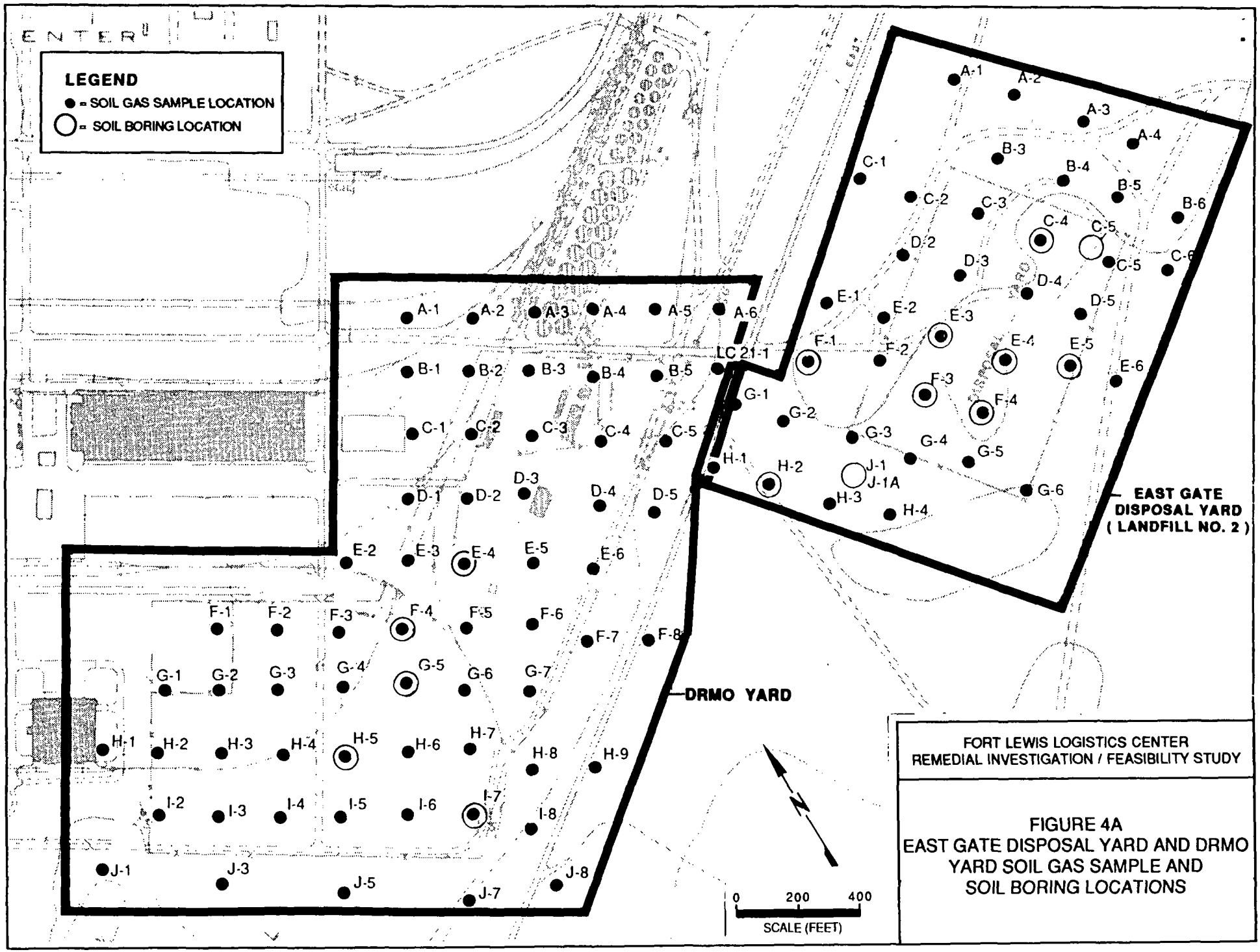
3/ Murray Creek and Lynn Lake are not a source of drinking water

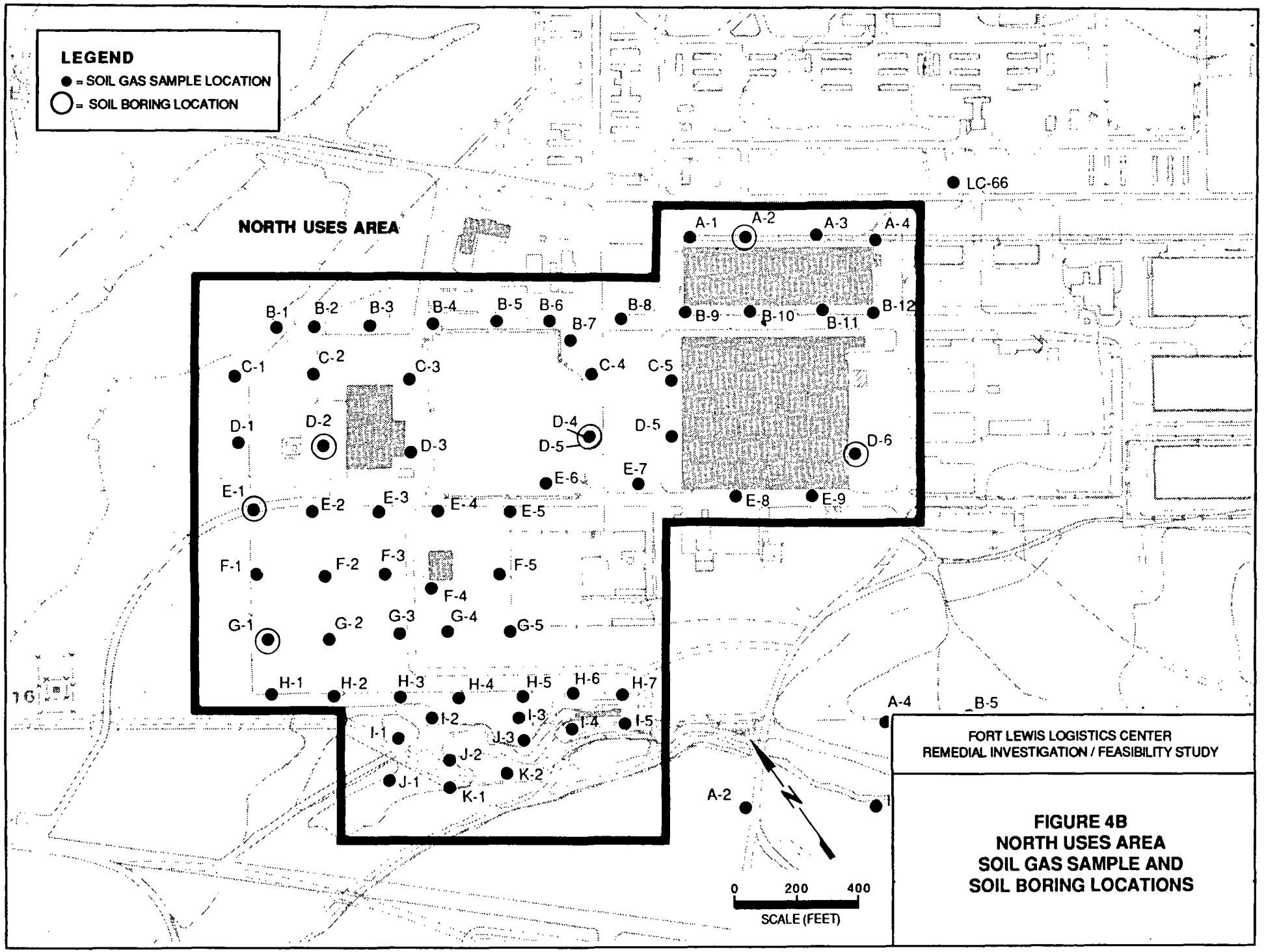
Sediment Sampling Results

Parameter	Frequency 1/ of Detection	Range of Concentration (ug/l)	Mean of Concentration (ug/l)	Range of DLs 2/ (ug/l)
TCE	5/10	0.49-3.0	1.6	0.4
DCE	0/10	-	-	0.2-0.6

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits


LEGEND
● = SOIL GAS SAMPLE LOCATION
◯ = SOIL BORING LOCATION
ENTER
EAST GATE DISPOSAL YARD (LANDFILL NO. 2)
DRMO YARD
A-1 A-2 A-3 A-4 A-5 A-6
B-1 B-2 B-3 B-4 B-5
C-1 C-2 C-3 C-4 C-5
D-1 D-2 D-3 D-4 D-5
E-1 E-2 E-3 E-4 E-5 E-6
F-1 F-2 F-3 F-4 F-5 F-6 F-7 F-8
G-1 G-2 G-3 G-4 G-5 G-6 G-7
H-1 H-2 H-3 H-4 H-5 H-6 H-7 H-8 H-9
I-1 I-2 I-3 I-4 I-5 I-6 I-7 I-8
J-1 J-3 J-5 J-7 J-8
LC 21-1
J-1A
0 200 400
SCALE (FEET)
FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIGURE 4A
EAST GATE DISPOSAL YARD AND DRMO YARD SOIL GAS SAMPLE AND SOIL BORING LOCATIONS


LEGEND
● = SOIL GAS SAMPLE LOCATION
◯ = SOIL BORING LOCATION
NORTH USES AREA
LC-66
A-1
A-2
A-3
A-4
B-1
B-2
B-3
B-4
B-5
B-6
B-7
B-8
B-9
B-10
B-11
B-12
C-1
C-2
C-3
C-4
C-5
D-1
D-2
D-3
D-4
D-5
D-6
E-1
E-2
E-3
E-4
E-5
E-6
E-7
E-8
E-9
F-1
F-2
F-3
F-4
F-5
G-1
G-2
G-3
G-4
G-5
H-1
H-2
H-3
H-4
H-5
H-6
H-7
I-1
I-2
I-3
I-4
I-5
J-1
J-2
J-3
K-1
K-2
0
200
400
SCALE (FEET)
FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIGURE 4B
NORTH USES AREA
SOIL GAS SAMPLE AND
SOIL BORING LOCATIONS

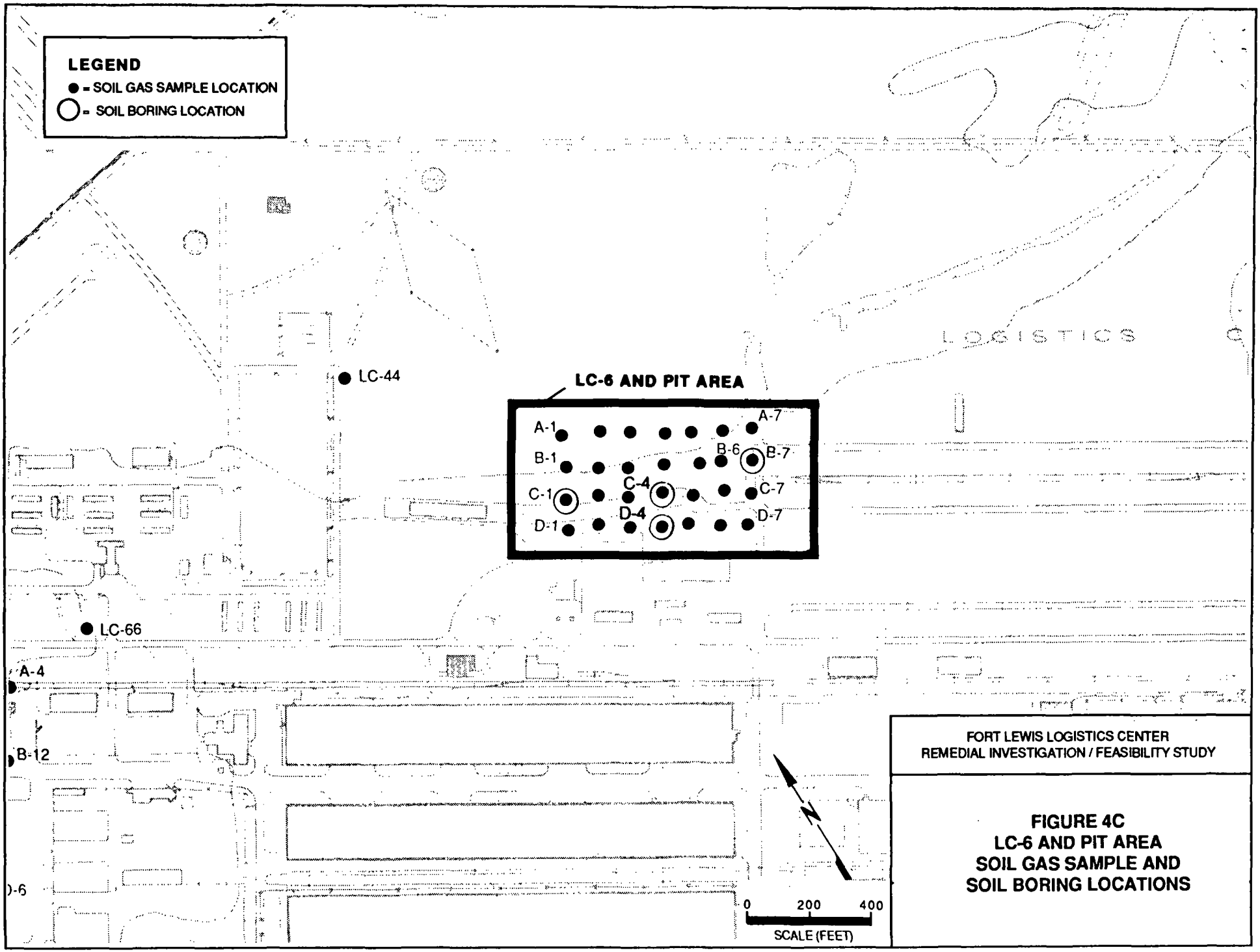

LEGEND
● = SOIL GAS SAMPLE LOCATION
◯ = SOIL BORING LOCATION
LOGISTICS
LC-44
LC-6 AND PIT AREA
A-1
A-7
B-1
B-6
B-7
C-1
C-4
C-7
D-1
D-4
D-7
LC-66
A-4
B-12
0
200
400
SCALE (FEET)
FORT LEWIS LOGISTICS CENTER
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIGURE 4C
LC-6 AND PIT AREA
SOIL GAS SAMPLE AND
SOIL BORING LOCATIONS

TABLE 4A

Fort Lewis Logistics Center
Soil Sampling Results

Inorganics Parameter	Frequency 1/ of Detection	Range of Concentration (mg/Kg)	Mean of Concentration (mg/Kg)	Range of 2/ DLs (mg/Kg)
Aluminum	5/5	11200-14100	13200	-
Antimony	0/5	-	-	0.8-14
Arsenic	5/5	1.8-15	5.1	-
Barium	5/5	42-91	62.4	-
Beryllium	0/5	-	-	0.4-1.2
Cadmium	5/5	1.0-2.7	2.1	-
Calcium	5/5	2340-4220	31.36	-
Chromium	5/5	6.9-29	16.7	-
Cobalt	5/5	7.3-13.0	9.7	-
Copper	5/5	9.4-24	17.9	-
Iron	5/5	9960-21200	16172	-
Lead	5/5	1.2-5.4	2.4	-
Magnesium	5/5	2240-5570	3998	-
Manganese	5/5	147-444	327	-
Mercury	4/5	0.1-1.9	0.6	0.1
Nickel	5/5	15-29	22.4	-
Potassium	5/5	310-1870	857	-
Selenium	0/5	-	-	0.1-1.2
Silver	0/5	-	-	0.1-2.5
Sodium	5/5	476-726	611	-
Thallium	1/5	0.5	0.5	1.9-2.5
Vanadium	5/5	20-37	28	-
Zinc	5/5	17-40	29	-
Cyanide	0/5	-	-	1.0-1.3

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

TABLE 4B

Fort Lewis Logistics Center
Soil Sampling Results

Volatiles Parameter	Frequency 1/ of Detection	Range of Concentration (mg/Kg)	Mean of Concentration (mg/Kg)	Range of DLs 2/ (mg/Kg)
Chloromethane	0/7	-		10-12500
Bromomethane	0/7	-		10-12500
Vinyl Chloride	0/7	-		10-12500
Chloroethane	0/7	-		10-12500
Methylene Chloride	0/1	-		6250
Acetone	0/2	-		10-12500
Carbon Disulfide	0/7	-		5-6250
1,1-Dichloroethylene (DCE)	0/7	-		5-6250
1,1-Dichloroethane (DCA)	0/7	-		5-6250
1,2-Dichloroethylene (DCE)	26/269	0.22-282000	21845	0.3-5
Chloroform	0/7	-		5-6250
1,2-Dichloroethane (DCA)	0/7	-		5-6250
2-Butanone	0/7	-		10-12500
1,1,1-Trichloroethane (TCA)	0/7	-		5-6250
Carbon Tetrachloride	0/7	-		5-6250
Vinyl Acetate	0/7	-		10-12500
Bromodichloromethane	0/7	-		5-6250
1,2-Dichloropropane	0/7	-		5-6250
cis-1,3-Dichloropropene	0/7	-		5-6250
Trichloroethylene (TCE)	104/269	0.11-240000	4975	0.2-5
Dibromochloromethane	0/7	-		5-6250
1,1,2-Trichloroethane	0/7	-		5-6250
Benzene	0/7	-		5-6250
Trans-1,3-Dichloropropene	0/7	-		5-6250
Bromoform	0/7	-		5-6250
4-Methyl-2-Pentanone	0/7	-		10-12500
2-Hexanone	0/7	-		10-12500
Tetrachloroethylene (PCE)	1/7	11000	11000	5
Toluene	1/7	14000	14000	5
1,1,2,2-Tetrachloroethane	0/7	-		5-6250
Chlorobenzene	0/7	-		5-6250
Ethyl benzene	1/7	9400	9400	5
Styrene	0/7	-		5-6250
Xylenes Total	1/7	78000	78000	5-15
2-Chloroethyl Vinyl ether	0/7	-		10-12500

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

TABLE 4C

Fort Lewis Logistics Center
Soil Sampling Results

Semivolatiles Parameter	Frequency 1/ of Detection	Range of Concentration (mg/Kg)	Mean of Concentration (mg/Kg)	Range of DLs 2/ (mg/Kg)
Phenol	0/5	-	-	360-430
bis(2-Chloroethyl)Ether	0/5	-	-	360-430
2-Chlorophenol	0/5	-	-	360-430
1,3-Dichlorobenzene	0/5	-	-	360-430
1,4-Dichlorobenzene	0/5	-	-	360-430
Benzyl Alcohol	0/5	-	-	360-430
1,2-Dichlorobenzene	0/5	-	-	360-430
2-Methylphenol	0/5	-	-	360-430
bis(2-Choloroisopropyl)Ether	0/5	-	-	360-430
4-Methylphenol	0/5	-	-	360-430
N-Nitroso-Dipropylamine	0/5	-	-	360-430
Hexachloroethane	0/5	-	-	360-430
Nitrobenzene	0/5	-	-	360-430
Isophorone	0/5	-	-	360-430
2-Nitrophenol	0/5	-	-	360-430
2,4-Dimethylphenol	0/5	-	-	1800-2150
Benzoic Acid	0/5	-	-	360-430
bis(2-Chloroethoxy)Methane	0/5	-	-	360-430
2,4-Dichlorophenol	0/5	-	-	360-430
1,2,4-Trichlorobenzene	0/5	-	-	360-430
Naphthalene	0/5	-	-	360-430
4-Chloroaniline	0/5	-	-	360-430
Hexachlorobutadiene	0/5	-	-	360-430
4-Chloro-3-Methylphenol	0/5	-	-	360-430
2-Methylnaphthalene	0/5	-	-	360-430
Hexachlorocyclopentadiene	0/5	-	-	360-430
2,4,6-Trichlorophenol	0/5	-	-	360-430
2,4,5-Trichlorophenol	0/5	-	-	1800-2150
2-Chloronaphthalene	0/5	-	-	360-430
2-Nitroaniline	0/5	-	-	1800-2150

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

TABLE 4C (continued)

Fort Lewis Logistics Center
Soil Sampling Results

Semivolatiles Parameter	Frequency 1/ of Detection	Range of Concentration (mg/Kg)	Mean of Concentration (mg/Kg)	Range of DLs 2/ (mg/Kg)
Dimethyl Phthalate	0/5	-	-	360-430
Acenaphthylene	0/5	-	-	360-430
2,6-Dinitrotoluene	0/5	-	-	1800-2150
3-Nitroaniline	0/5	-	-	360-430
Acenaphthene	0/5	-	-	360-430
2,4-Dinitrophenol	0/5	-	-	1800-2150
4-Nitrophenol	0/5	-	-	1800-2150
Dibenzofuran	0/5	-	-	360-430
2,4-Dinitrotoluene	0/5	-	-	360-430
Diethylphthalate	0/5	-	-	360-430
4-Chlorophenyl-phenyl Ether	0/5	-	-	360-430
Fluorene	0/5	-	-	360-430
4-Nitroaniline	0/5	-	-	1800-2150
4,6-Dinitro-2-Methylphenol	0/5	-	-	1800-2150
N-Nitrosodiphenylamine	0/5	-	-	360-430
4-Bromophenyl-phenylether	0/5	-	-	360-430
Hexachlorobenzene	0/5	-	-	360-430
Pentachlorophenol	0/5	-	-	1800-2150
Phenanthrene	0/5	-	-	360-430
Anthracene	0/5	-	-	360-430
Di-n-Butylphthalate	0/5	-	-	360-430
Fluoranthene	0/5	-	-	360-430
Pyrene	0/5	-	-	360-430
Butylbenzylphthalate	0/5	-	-	360-430
3,3'-Dichlorobenzidine	0/5	-	-	590-710
Benzo(a)Anthracene	0/5	-	-	360-430
Chrysene	0/5	-	-	360-430
bis(2-Ethylhexyl)Phthalate	0/5	-	-	360-430
Di-n-Octyl Phthalate	0/5	-	-	360-430
Benzo(b)Fluoranthene	0/5	-	-	360-430
Benzo(k)Fluoranthene	0/5	-	-	360-430
Benzo(a)Pyrene	0/5	-	-	360-430
Indeno(1,2,3-cd)Pyrene	0/5	-	-	360-430
Dibenz(a,h)Anthracene	0/5	-	-	360-430
Benzo(g,h,i)Perylene	0/5	-	-	360-430

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

TABLE 4D

Fort Lewis Logistics Center
Soil Sampling Results

Pesticides/PCBs Parameter	Frequency 1/ of Detection	Range of Concentration (mg/Kg)	Mean of Concentration (mg/Kg)	Range of DLs 2/ (mg/Kg)
alpha-BHC	0/5	-	-	8.1-9.8
beta-BHC	0/5	-	-	8.1-9.8
delta-BHC	0/5	-	-	8.1-9.8
gamma-BHC(Lindane)	0/5	-	-	8.1-9.8
Heptachlor	0/5	-	-	8.1-9.8
Aldrin	0/5	-	-	8.1-9.8
Heptachlor epoxide	0/5	-	-	8.1-9.8
Endosulfan I	0/5	-	-	8.1-9.8
Dieldrin	0/5	-	-	16-20
4,4'-DDE	0/5	-	-	16-20
Endrin	0/5	-	-	16-20
Endosulfan II	0/5	-	-	16-20
4,4'-DDD	0/5	-	-	16-20
Endosulfan sulfate	0/5	-	-	16-20
4,4'-DDT	0/5	-	-	16-20
Methoxychlor	0/5	-	-	81-98
Endrin ketone	0/5	-	-	16-20
Chlordane	0/5	-	-	81-98
Toxaphene	0/5	-	-	160-200
Aroclor-1016	0/5	-	-	81-98
Aroclor-1221	0/5	-	-	81-98
Aroclor-1232	0/5	-	-	81-98
Aroclor-1242	0/5	-	-	81-98
Aroclor-1248	0/5	-	-	81-98
Aroclor-1254	0/5	-	-	160-200
Aroclor-1260	0/5	-	-	160-200

1/ Frequency of Detection=number of detections/number of samples analyzed

2/ Range of DLs=range of detection limits

VII. SUMMARY OF SITE RISKS

The baseline risk assessment considered both human health risks and ecological risks. The human receptors considered were on-post workers, on-post residents, and off-site residents. The biological receptors included aquatic organisms and local small mammals. The Army prepared a human health and ecological endangerment assessment using the Maximum Acceptable Concentration (MAC) methodology (Final Endangerment Assessment Report, February 1990). Because EPA generally does not use or recommend the MAC approach, EPA Region 10 also prepared an assessment of human health risks at the site using "EPA Region 10 Exposure Parameters" (January 31, 1990) and the Risk Assessment Guidance for Superfund (RAGS): Human Health Evaluation Manual Part A (December 1989). The results are similar, in most cases, to the Army's Endangerment Assessment. The results from the EPA human health risk assessment are discussed below.

A. Human Health Risks

Adverse effects resulting from exposure to chemical contaminants have been grouped into two categories: carcinogenic effects and noncarcinogenic effects (e.g., effects on organ systems, reproductive and developmental effects). In the baseline risk assessment, risk has been estimated for exposure to chemicals found at the Logistics Center. The risks presented do not include risks or rates of illness (e.g., the normal cancer incidence is about 1 in 4 individuals) normally expected in the population.

Carcinogenic risk is estimated for chemicals known or expected to cause cancer as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogen. To estimate this risk, a mathematical model is used to derive a relationship (slope factor) between exposure (dose) and cancer incidence (response) from human or animal studies. Since there is much uncertainty in this procedure, the upper 95% confidence limit of the dose-response relationship is normally used to derive the slope factor so as not to underestimate the risk. Slope factors are combined with site exposure information to estimate the incremental cancer risk, which is usually expressed in scientific notation (e.g., 1×10^{-4}). An excess lifetime cancer risk of 1×10^{-4} indicates that, as a plausible upperbound, an individual has a one in ten thousand chance of developing cancer (over the normal cancer risk of 1 in 4) as a result of site-related exposure to a carcinogen. For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upperbound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response (NCP 1990).

For noncarcinogens, the measure used to describe the potential for toxicity to occur in an individual is not expressed as a probability. The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified period (e.g., lifetime) with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called a Hazard Quotient. The Hazard Index (HI) is the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. Potential noncarcinogenic effects may be of concern if the HI exceeds unity (i.e., HI > 1).

1. Chemicals of Concern

Data collected during the RI were used to identify chemicals present at the site. Media sampled included groundwater, soils, surface water, and sediments. All chemicals were included in the assessment unless: a) they were not detected in any of the above media; b) toxicity reference values (i.e., Reference dose [Rfds] or cancer slope factors) have not been developed for a chemical; or c) the chemical is an essential nutrient. Two exceptions to these criteria are thallium and vinyl chloride. Neither of these were detected in groundwater, but they were included in the EPA assessment using half of their respective detection limits (per RAGS guidance, 1990) since the risk at the detection limit is significant. Table 5 lists chemicals included in the baseline risk assessment based on the RI data and above screening criteria.

2. Exposure Assessment

For this assessment, exposure was assumed to occur in the following settings/scenarios:

TABLE 5 CHEMICALS OF CONCERN

CONTAMINANT	GROUNDWATER	SOIL	SURFACE WATER
Arsenic	X	X	
Barium	X	X	
Cadmium	X	X	
Chromium	X	X	
Lead	X	X	
Manganese	X	X	
Mercury	X	X	
Nickel	X	X	
Thallium	X	X	
Vanadium	X	X	
Zinc	X	X	
Trichloroethylene	X	X	X
cis 1,2 Dichloroethylene	X	X	X
Toluene		X	
Ethylbenzene		X	
Total Xylenes		X	
Tetrachloroethylene	X	X	
1,1,1 Trichloroethane	X	X	
Vinyl Chloride	X	X	

a. Future on-post worker near the East Gate Disposal Yard assuming a 40-year career exposure;

b. Future on-post resident living near the East Gate Disposal Yard assuming a 75-year lifetime exposure; and

c. Future off-site resident nearest to contaminants originating at the Logistics Center assuming a 75-year lifetime exposure.

Although a future on-post resident scenario was considered in the baseline risk assessment, it is not probable that the future use of the Logistics Center will change from its current use as an industrial facility. The Logistics Center will continue to provide required maintenance and supply activities to support troop activities for the foreseeable future.

Exposure routes considered for each media are listed below.

Groundwater	Surface Water	Soil
ingestion	ingestion	ingestion
dermal contact	dermal contact	dermal contact
vapor inhalation	vapor inhalation	vapor inhalation
	fish consumption	particulate inhalation

Dermal contact was qualitatively evaluated in the assessment due to the large uncertainty in assessing absorption through the skin and due to the lack of toxicity reference values for dermal exposures.

3. Risk Characterization

a. Exposure Point Concentrations: Soil and groundwater concentrations listed in Table 6 were used to estimate exposure to the on-site worker, on-post resident, and off-post resident. Soil data suggest that the East Gate Disposal Yard has the highest levels of soil contamination. Therefore, soil data from this area were used to estimate exposure point concentrations. Generally, maximum concentration values were used to calculate risks because insufficient data (< 20 samples) were available to accurately estimate an upper 95% confidence limit on the average. Likewise, groundwater data suggest that the highest contamination exists near the East Gate Disposal Yard. Seven wells in this area were selected to estimate exposure point concentrations for TCE and DCE. Since few (< 20) data points were available to estimate the upper 95% confidence level for each well, the maximum TCE and DCE concentrations of these wells were used. A subset of all wells were sampled for metals and other organics. Therefore, maximum concentrations from wells near the East Gate Disposal Yard (LC-64a, LC-21-1) and other areas of the Logistics Center (LC-66b, LC-40a) were used to estimate exposure. Only metals data from unfiltered samples (May 1988 sampling event) were used to estimate exposure, as suggested in the RAGS guidance. In only two cases, arsenic and PCE, did measured concentrations in other wells slightly exceed concentrations used to estimate exposure.

Contaminants in soil may enter the atmosphere by either volatilization or through disturbances which suspend particulate matter. Air modeling was performed using the techniques outlined in the Superfund Exposure Assessment Manual (SEAM) (EPA 1988) to estimate soil vapor and particulate inhalation concentrations.

b. Chemical Intake by Exposure Pathway: Chemical intake and average daily dose (mg/kg/day) were estimated for each exposure pathway using the exposure point concentrations and other exposure parameters, such as soil and water ingestion rate, and body weight. Pathway-specific equations from the RAGS guidance were used to estimate intake and dose.

Tables 7, 8, and 9 summarize the carcinogenic and non-carcinogenic risks for off-site resident, on-post worker, and future on-post resident for each chemical of concern and media exposure route, as well as, the total combined risk from all media.

TABLE 6 EXPOSURE POINT CONCENTRATIONS

	GROUNDWATER CONCENTRATION (UG/L)		SOIL CONCENTRATION (MG/KG)	
	AVE	MAX	AVE	MAX
ARSENIC	3.2	4.2	4.4	4.4
BARIUM	43.0	53.0	48.0	48.0
CADMIUM	2.0	0.5	2.6	2.6
CHROMIUM	14.7	34.0	22.0	22.0
MANGANESE	1417.0	4000.0	423.0	423.0
MERCURY	0.3	0.6	0.1	0.1
NICKEL	85.3	100.0	27.0	27.0
THALLIUM	5.0	5.0	1.3	1.3
VANADIUM			35.0	35.0
ZINC	183.0	210.0	38.0	38.0
TRICHLOROETHYLENE	324.6	2400.0	120.0	240.0
cis 1,2 DICHLOROETHYLENE	24.3	130.0	141.0	282.0
TOLUENE			7.0	14.0
ETHYL BENZENE			4.7	9.4
TOTAL XYLENES			39.0	78.0
TETRACHLOROETHYLENE	2.5	2.5	5.5	11.0
1,1,1 TRICHLOROETHANE	2.5	2.5	1.6	3.1
VINYL CHLORIDE	5.0	5.0	6.3	12.5
LEAD	17.0	28.0	5.4	5.4

SURFACE WATER CONCENTRATION (UG/L)

	TCE	cis DCE
WATER BODY	MAX	MAX
LYNN LAKE	46.0	23.0
MURRAY CREEK	4.5	1.7

TABLE 7 FUTURE OFFSITE RESIDENT RISK

	GROUNDWATER				SOIL						SURFACE WATER (MURRAY CREEK) FISH CONSUMPTION ONLY		TOTAL RISK	
	INGESTION		SHOWERING		INGESTION		PARTICULATE INHALATION		VAPOR INHALATION					
CONTAMINANT	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX
ARSENIC	2.3E-04	9.1E-02					2.5E-10	1.6E-08					2.3E-04	9.1E-02
BARIUM		2.3E-02						1.8E-06						2.3E-02
CADMIUM		2.2E-02					6.1E-11	1.9E-08					6.1E-11	2.2E-02
CHROMIUM		1.5E-01					3.5E-09	1.6E-08					3.5E-09	1.5E-01
MANGANESE		4.3E-01						5.1E-06						4.3E-01
MERCURY		4.3E-02						1.2E-09						4.3E-02
NICKEL		1.1E-01					1.8E-10	4.9E-09					1.8E-10	1.1E-01
THALLIUM		1.5E+00						6.5E-08						1.5E+00
VANADIUM								1.8E-08						1.8E-08
ZINC		2.3E-02						6.9E-10						2.3E-02
TRICHLOROETHYLENE	8.3E-04	7.0E+00	1.8E-03				5.5E-12	1.2E-07	3.5E-10	7.3E-06	7.9E-07	9.5E-03	2.6E-03	7.0E+00
cis 1,2 DICHLOROETHYLENE		1.4E-01						5.1E-08		1.4E-05		2.7E-04		1.4E-01
TOLUENE								9.0E-11		1.7E-08				1.7E-08
ETHYL BENZENE								3.4E-10		1.2E-08				1.2E-08
TOTAL XYLENES								3.3E-09		2.3E-07				2.3E-07
TETRACHLOROETHYLENE	4.0E-06	5.4E-03	1.6E-05				1.4E-13	4.0E-09	2.9E-11	8.2E-07			2.0E-05	5.4E-03
1,1,1 TRICHLOROETHANE		6.0E-04		1.1E-03				3.8E-11		4.9E-08				1.7E-03
VINYL CHLORIDE	3.6E-04	1.1E-01	9.1E-05				7.1E-12	4.6E-08	1.3E-07	8.2E-04			4.5E-04	1.1E-01
TOTALS	1.4E-03	9.7E+00	1.9E-03	1.1E-03	0.0E+00	0.0E+00	4.0E-09	7.3E-06	1.3E-07	8.5E-04	7.9E-07	9.8E-03	3.3E-03	9.7E+00

TABLE 8 FUTURE ONPOST WORKER RISK

	GROUNDWATER				SOIL						SURFACE WATER (LYNN LAKE)		TOTAL RISK	
	INGESTION		SHOWERING		INGESTION		PARTICULATE INHALATION		VAPOR INHALATION		FISH CONSUMPTION ONLY			
CONTAMINANT	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX
ARSENIC	6.72E-05	7.2E-02			2.11E-06	2.3E-03	9.72E-10	1.2E-07					6.9E-05	7.4E-02
BARIUM		1.8E-02				4.9E-04		1.3E-05						1.9E-02
CADMIUM		1.7E-02				2.7E-03	2.34E-10	1.4E-07					2.3E-10	2.0E-02
CHROMIUM		1.2E-01				2.3E-03	1.33E-08	1.2E-07					1.3E-08	1.2E-01
MANGANESE		3.4E-01				1.1E-03		3.9E-05						3.4E-01
MERCURY		3.4E-02				1.7E-04		9.2E-09						3.4E-02
NICKEL		8.6E-02				6.9E-04	6.76E-10	3.7E-08					6.8E-10	8.6E-02
THALLIUM		1.2E+00				9.2E-03		4.9E-07						1.2E+00
VANADIUM						2.6E-03		1.4E-07						2.6E-03
ZINC		1.8E-02				9.8E-05		5.2E-09						1.8E-02
TRICHLOROETHYLENE	2.41E-04	5.6E+00	5.3E-04		7.24E-07	1.7E-02	2.1E-11	9.0E-07	1.35E-09	5.6E-05	1.5E-06	1.8E-02	7.7E-04	5.6E+00
cis 1,2 DICHLOROETHYLENE		1.1E-01				7.3E-03		3.9E-07		1.1E-04		2.0E-03		1.2E-01
TOLUENE						2.4E-05		6.8E-10		1.3E-07				2.4E-05
ETHYL BENZENE						4.8E-05		2.6E-09		1.3E-07				4.8E-05
TOTAL XYLENES						2.0E-05		2.5E-08		1.8E-06				2.2E-05
TETRACHLOROETHYLENE	1.17E-06	4.3E-03	4.7E-06		1.54E-07	5.7E-04	5.35E-13	3.0E-08	1.17E-10	6.7E-06			6.0E-06	4.9E-03
1,1,1 TRICHLOROETHANE		4.8E-04		3.1E-04		1.8E-05		2.9E-10		3.7E-07				8.0E-04
VINYL CHLORIDE	1.05E-04	8.6E-02	2.7E-05		7.89E-06	6.4E-03	2.72E-11	3.5E-07	4.92E-07	6.3E-03			1.4E-04	9.8E-02
TOTALS	4.1E-04	7.7E+00	5.6E-04	3.1E-04	1.1E-05	5.3E-02	1.5E-08	5.5E-05	4.9E-07	6.4E-03	1.5E-06	2.0E-02	9.9E-04	7.8E+00

TABLE 9. FUTURE ONPOST RESIDENT RISK

	GROUNDWATER				SOIL						SURFACE WATER (LYNN LAKE) FISH CONSUMPTION ONLY		TOTAL RISK	
	INGESTION		SHOWERING		INGESTION		PARTICULATE INHALATION		VAPOR INHALATION					
	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX	CANCER RISK	HAZARD INDEX
ARSENIC	2.31E-04	9.1E-02			1.13E-05	3.6E-03	2.79E-09	1.8E-07					2.4E-04	9.4E-02
BARIUM		2.3E-02				7.9E-04		1.9E-05						2.4E-02
CADMIUM		2.2E-02				4.3E-03	6.70E-10	2.1E-07					6.7E-10	2.6E-02
CHROMIUM		1.5E-01				3.6E-03	3.81E-08	1.8E-07					3.8E-08	1.5E-01
MANGANESE		4.3E-01				1.7E-03		5.6E-05						4.3E-01
MERCURY		4.3E-02				2.7E-04		1.3E-08						4.3E-02
NICKEL		1.1E-01				1.1E-03	1.94E-09	5.4E-08					1.9E-09	1.1E-01
THALLIUM		1.5E+00				1.5E-02		7.1E-07						1.6E+00
VANADIUM						4.1E-03		2.0E-07						4.1E-03
ZINC		2.3E-02				1.6E-04		7.6E-09						2.3E-02
TRICHLOROETHYLENE	8.30E-04	7.0E+00	1.8E-03		3.86E-06	2.7E-02	1.72E-10	1.3E-06	1.11E-08	8.1E-05	3.2E-06	3.9E-02	2.6E-03	7.1E+00
cis 1,2 DICHLOROETHYLENE		1.4E-01				1.2E-02		5.6E-07		1.6E-04		6.3E-03		1.6E-01
TOLUENE						3.8E-05		9.8E-10		1.9E-07				3.9E-05
ETHYL BENZENE						7.7E-05		3.8E-09		1.9E-07				7.8E-05
TOTAL XYLENES						3.2E-05		3.6E-08		2.6E-06				3.5E-05
TETRACHLOROETHYLENE	4.01E-06	5.4E-03	1.6E-05		8.21E-07	9.1E-04	1.53E-12	4.4E-08	3.36E-10	9.6E-06			2.1E-05	6.3E-03
1,1,1 TRICHLOROETHANE		6.0E-04		1.1E-03		2.9E-05		4.2E-10		5.4E-07				1.7E-03
VINYL CHLORIDE	3.61E-04	1.1E-01	9.1E-05		4.21E-05	1.0E-02	1.56E-10	5.0E-07	2.82E-06	9.1E-03			5.0E-04	1.3E-01
TOTALS	1.4E-03	9.7E+00	1.9E-03	1.1E-03	5.8E-05	8.4E-02	4.4E-08	8.0E-05	2.8E-06	9.3E-03	3.2E-06	4.6E-02	3.4E-03	9.8E+00

Currently, neither a reference dose nor a cancer slope factor are available to quantitatively evaluate risk from lead exposure. Concentrations of lead in unfiltered groundwater samples were found to range from 10 to 20 ug/l. In a memorandum dated June 21, 1990 from EPA Office of Emergency and Remedial Response (OERR) and Office of Waste Programs Enforcement (OWPE) to EPA Region IV, it was recommended that a final cleanup level of 15 ug/l for lead in groundwater usable for drinking water is protective for Superfund remedial actions. A concentration of lead of 15 ug/l in drinking water should generally correlate with a blood lead level below the concern level of 10 ug/dl. It is not clear whether site data from the Logistics Center represent a significant exceedance of this level, nor whether lead is natural or anthropogenic (man-made) in nature. Soil concentrations of lead ranged from 1.2 to 5.4 mg/kg over the Logistics Center. These levels may be compared to the suggested lead cleanup levels of 500 to 1000 mg/kg for Superfund remedial actions (OWSER Directive #9355.4-02). Further discussion of lead is included in the section entitled **Remediation Goals**.

The estimated carcinogenic risk from vinyl chloride of > $1x10^{-4}$ resulted principally from the use of 5 ug/l (one-half the detection limit) as the groundwater exposure point concentration. Vinyl chloride has not been detected in any groundwater well to date.

Arsenic also exhibited a carcinogenic risk of > $1x10^{-4}$ for groundwater ingestion in the off-site resident exposure. The exposure concentration for arsenic in groundwater of 4.2 ug/l may be lower than the background concentration for arsenic in the Fort Lewis area. Further discussion of arsenic is included in the section entitled **Remediation Goals**.

4. Uncertainty

Major components of the assessment which decreased the certainty of the results were the toxicity reference values used, dermal contact pathway risks, and site characterization data. Due to the uncertainty in these and other areas, conservative assumptions were made in order to be protective of human health. Therefore, cancer and noncancer risk estimates must be carefully interpreted. This is particularly important when evaluating noncarcinogenic effects where uncertainty factors of 2 to 3 orders of magnitude are used in dose-response assessment. Given this uncertainty and other conservative assumptions in the exposure assessment, exceeding a hazard index or quotient of 1.0 by several fold may not be significant.

5. Toxicity Characteristics

A brief discussion of the toxicity of the three major contaminants of concern is presented below.

Trichloroethylene (TCE): Acute effects from inhalation of high air concentrations of TCE have been shown to induce anesthetic, analgesic, neurotoxic and behavioral effects (USEPA 1985). Principal targets for inhaled TCE are the central nervous system (CNS), liver, kidney, and hematological system (ATSDR 1988). The acute oral lethal dose of TCE in laboratory rats is 7,193 mg/kg (NIOSH 1984).

Chronic effects in workers occupationally exposed to TCE concentrations (14 to 85 ppm) for an average of 3.75 years experienced effects such as vertigo, headache, and short-term memory loss (ATSDR 1988). In long-term studies with experimental animals, principal target organs following chronic exposures are the CNS, liver, kidney, and hematological system.

Studies investigating the carcinogenic potential of TCE found that TCE produced hepatocellular and testicular Leydig cell carcinomas as well as renal and lung adenomas. Under EPA's Proposed Guidelines for Carcinogen Assessment, TCE is classified as a probable human carcinogen.

Cis 1,2 - DICHLOROETHYLENE (DCE): In humans, 1,2-DCE is a central nervous system depressant at high concentrations. Hepatic effects, including significant microscopic liver changes, have been observed in studies conducted where rats received 200 mg/l of DCE in drinking water (Quast et al., 1983). In another study, liver enzyme levels were increased in rats given a single 400 mg/kg dose (Jenkins et al., 1972).

According to EPA's proposed guidelines for carcinogenic risk assessment, cis-1,2-DCE has been classified in Group D. This category applies to agents for which there is inadequate evidence of carcinogencity from animal studies.

TETRACHLOROETHYLENE (PCE): The principal toxic effects of PCE in humans and animals from both acute and longer-term exposures include central nervous system (CNS) depression and fatty infiltration of the liver and kidney with concomitant changes in serum enzyme levels indicative of tissue damage. Hepatoxic effects reported in humans exposed to PCE include cirrhosis, toxic hepatitis, liver cell necrosis, hepatomegaly, and altered liver function (EPA, 1985).

EPA's Carcinogen Assessment Group has classified PCE in Group B2 - Probable Human Carcinogen. Significantly increased dose related incidences of hepatocellular carcinomas were observed in mice exposed during inhalation studies (National Toxicology Program [NTP], 1986). In the NTP study, increased incidences of mononuclear cell leukemia were seen in both sexes of rats and increased dose-related incidences of renal adenomas and carcinomas were seen in males only.

B. Environmental Risks

The results of the qualitative ecological assessment indicate that the concentrations of TCE and DCE in surface water and sediments of the on-post and off-post lakes do not result in adverse toxicological effects to aquatic organisms. In each of the lakes, maximum concentrations of TCE and DCE were below levels necessary to trigger acute effects. TCE concentrations in sediments were very low and DCE was not detected in any of the samples collected. Interstitial water concentrations estimated from the sediment concentrations of TCE were well below those necessary to initiate acute and chronic aquatic toxicity.

No endangered species or critical habitats were identified at the Logistics Center.

VIII. DESCRIPTION OF ALTERNATIVES

A. Soil Alternatives

Soil alternatives were evaluated within the FS process while the baseline risk assessment was being finalized. The baseline risk assessment subsequently indicated that the levels of residual soil contamination correspond to a carcinogenic risk of $1x10^{-5}$ and a noncarcinogenic hazard index of 0.06. This baseline risk for soil is within the acceptable exposure levels (i.e., between 10^{-4} and 10^{-6}) that are protective of human health as promulgated in the NCP (55 FR 8848). Therefore, remediation of soil is not included as part of the selected remedy.

B. Groundwater Alternatives

A complete listing of the applicable or relevant and appropriate requirements (ARARs) are listed and summarized in the section entitled **Statutory Determinations**.

The principal regulations for the groundwater alternatives are the Clean Water Act (CWA)(33 USC 1251), the Safe Drinking Water Act (SDWA) (40 USC 300), the Resource Conservation and Recovery Act (RCRA)(42 USC 6901), the Water Pollution Control Act (Chapter 90.48 RCW), and the Clean Air Act (Chapter 70.94 RCW).

Under the CWA: 1) State Antidegradation Requirements/Use Classification require every state to classify all the waters within its boundaries according to intended use. The aquifers beneath the Logistics Center, including the contaminated unconfined aquifer, are Class I (i.e., drinking water) aquifers; 2) CWA section 304 specifies ambient water quality criteria (AWQC) which were developed for the protection of human health and aquatic life. The AWQC were compared to contaminant levels found in surface waters potentially affected by the Logistics Center (Table 3) and are discussed further in the section

entitled **Remediation Goals**; and 3) CWA section 301(b) requires that, at a minimum, all direct discharges meet technology-based limits for conventional pollutant control technology. Because there are no national effluent limitations regulations for releases from CERCLA sites, technology-based treatment requirements are determined on a case-by-case basis using best professional judgement. Air stripping was the type of pollutant control technology evaluated for the groundwater alternatives. Air stripping is a proven technology for treatment of the VOC-contaminated groundwater. For example, the technology should treat TCE to better than MCLs (approximately 0.5 ug/l).

CERCLA section 121(d)(2)(A) requires on-site CERCLA remedies to attain standards or levels of control established under the SDWA (i.e., MCLs or MCLGs [maximum contaminant level goals]). According to the NCP (55 FR 8848), where MCLGs are set at zero, the remedial actions shall attain MCLs for ground or surface waters that are current or potential sources of drinking water. MCLs are the remediation goals for the Logistics Center and are discussed later in the section entitled **Remediation Goals**.

Under RCRA, the principal wastes (i.e., TCE and DCE) are RCRA-listed spent halogenated solvents (F001). Because the groundwater is contaminated by RCRA hazardous wastes, it must be managed as a hazardous waste until it no longer contains the hazardous wastes. An air stripper will be used to treat the contaminated groundwater such that the concentration of hazardous wastes will be below health-based levels (i.e., less than MCLs or MCLGs). After treatment, the groundwater will no longer contain a hazardous waste and would not be regulated as a hazardous waste.

Ambient concentrations of toxic air contaminants in the Puget Sound region are regulated by the Puget Sound Air Pollution Control Agency (PSAPCA) pursuant to the State of Washington Clean Air Act (Chapter 70.94 RCW) and Implementation of Regulations for Air Contaminant Sources (Chapter 173-403 WAC).

The Best Available Control Technology (BACT) is required by PSAPCA for new sources of toxic air contaminants. BACT means an emission limitation based on the maximum degree of reduction possible for a given source through application of production processes and available methods. On a case-by-case basis, PSAPCA determines the achievable BACT based upon factors such as energy, environmental, and economic impacts. Subsequent to BACT, PSAPCA evaluates toxic air contaminant emissions from the source against Acceptable Source Impact Levels (ASILs) adopted by the Agency. The ASIL for TCE is 0.8 ug/m^3. Pre-conceptual design concentrations from the FS estimate TCE air emissions from the air strippers at 0.060 ug/m^3.

The air stripping vendor may perform a bench-scale treatability study to obtain information to design the air stripper. A pilot study may not be required for the air stripper since air stripping is a well-developed technology. A pump test may be required to obtain engineering data for the design of the extraction and discharge systems. Also, the need for metals removal to facilitate the air stripping technology will be evaluated during design.

1. No Action (monitoring only)

The NCP requires that the "no action" alternative be considered for every site. Under this alternative, no remedial actions would be taken beyond those already in place (i.e., providing an alternative water supply to residents with contaminated wells). Monitoring would be implemented only to evaluate changes in the contaminant plume. The "no action" alternative is not protective of human health or the environment and does not meet ARARs. Since this alternative does not change contaminant concentration or exposure, the residual risk is equivalent to the baseline risk.

2. Extract and Treat Downgradient of the Site

The purpose of this alternative is to reduce and control the release of the contaminants into the unconfined aquifer downgradient of the Logistics Center. The alternative consists of installing extraction wells downgradient (i.e., northwestern boundary) of the Logistics Center. During operation, groundwater would be pumped from the wells and treated in an air stripping tower. Assuming a treatment rate of

5000 gallons per minute (gpm), an influent TCE concentration of 70 ug/l, and an air-liquid ratio of 50:1, the air stripper should treat the TCE to less than 5 ug/l.

The treated groundwater would be discharged back to the ground into passive discharge trenches downgradient of the extraction wells. The exact number and location of extraction wells and discharge trenches will be determined during design.

Administrative and institutional controls may include provisions for alternate water supply, access restrictions, notification to appropriate agencies, and public awareness.

If additional existing private drinking water wells are found to be contaminated, the residents will be offered connections to an alternate water supply (e.g., Lakewood Water District). The Army will update the affected communities and municipalities of the remedial action progress, continue to discourage use of private wells for drinking water purposes, and monitor the contaminated private wells.

A long-term monitoring program would be instituted using both on- and off-site wells to measure the effectiveness of the remedial action during implementation.

Under alternative 2, remediation of the Logistics Center contaminated groundwater plume may require 50 years or more.

The reasonable maximum exposed (RME) individual for the off-post resident scenario experiences a combined residual risk at remediation goals for all contaminants and all pathways of 5×10^{-5} (carcinogenic risk) and a hazard index of 0.91 (noncarcinogenic risk).

3. Extract and Treat Downgradient of the Logistics Center and Near Source Areas

The purpose of this alternative is to reduce and control the release of the contaminants into the unconfined aquifer beneath and downgradient of the Logistics Center in a significantly shorter time period than Alternative 2. Also, the NCP (55 FR 8849) requires that for groundwater response actions, alternatives be developed that attain site-specific remediation levels within different restoration time periods using one or more different technologies.

The alternative consists of installing extraction wells downgradient (i.e., northwestern boundary) of the Logistics Center and near the areas of highest contaminant concentration in the groundwater. The exact number and location of extraction wells will be determined during design. Placing wells in the areas of highest contamination should expedite remediation of the groundwater beneath the Logistics Center.

During operation, groundwater would be pumped from the wells and treated in air stripping towers at two locations. For the downgradient treatment system, the FS assumed a flowrate of 5000 gpm and an influent TCE concentration of 70 ug/l. For the treatment system near the areas of highest contamination, the FS assumed a flowrate of 2000 gpm and an influent TCE concentration of 145 ug/l. Based on these assumptions and an air-liquid ratio of 50:1, the air stripper should treat the TCE to less than 5 ug/l.

The treated groundwater would be discharged to the ground into passive discharge trenches. One trench will be located upgradient from the wells in the areas of highest contaminant concentrations. Locating a discharge trench upgradient would expedite groundwater remediation by facilitating flushing of secondary sources.

This alternative includes the administrative and institutional controls and long-term monitoring as described in Alternative 2.

Remediation of the Logistics Center contaminated groundwater plume would be completed in approximately 30 years.

The reasonable maximum exposed (RME) individual for the off-post resident scenario experiences a combined residual risk at remediation goals for all contaminants and all pathways of 5×10^{-5} (carcinogenic risk) and a Hazard Index of 0.91 (noncarcinogenic risk).

IX. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

The relative performance of each remedial alternative was evaluated in relation to three categories of criteria: 1) threshold criteria (a required level of performance); 2) primary balancing criteria (technical advantages and disadvantages); and 3) modifying criteria (overall evaluation). The nine evaluation criteria and the results of the evaluation are discussed below.

A. Threshold criteria

The remedial alternatives were first evaluated in relation to the threshold criteria: overall protection of human health and the environment, and compliance with ARARs. The threshold criteria must be met by all alternatives that are considered for further evaluation as remedies for the site. A summary of the relative performance of the groundwater alternatives is included in Table 10.

1. Overall Protection of Human Health and the Environment. This criteria addresses whether or not a remedial alternative provides adequate protection and describes how risks are eliminated, reduced, or controlled through treatment and engineering or institutional controls.

Both alternatives 2 and 3 provide overall protection once remediation is complete by reducing the risk to human health and the environment from the contaminated groundwater. Because the groundwater will meet MCLs after treatment and discharge, the unconfined aquifer may be restored for use as drinking water in approximately 30 or 50 years. In addition, under both alternatives, the groundwater would be treated to effluent concentrations less than MCLs before being discharged to the ground. During remediation, the groundwater discharged to the aquifer would meet MCLs and would reduce the risks downgradient of the Logistics Center.

Alternative 2 would have a greater impact on human health and the environment because it would allow at least 20 additional years of potential exposure to contaminated groundwater. Alternative 3 significantly reduces the time required for remediation of the contaminated aquifer by adding extraction and treatment of the most contaminated portions of the plume. This results in a reduction of exposure duration from impacts of both contaminated groundwater and air stripping emissions.

The no action alternative involves no remedial action and is not protective of human health or the environment.

2. Compliance with ARARs. This criteria addresses whether or not a remedial alternative will meet all of the applicable or relevant and appropriate requirements or provide grounds for invoking a waiver.

Alternatives 2 and 3 will achieve compliance with the ARARs discussed in the section entitled **Statutory Determinations**.

The no action alternative is not compliant with ARARs because there is no reduction of contamination in the groundwater. The groundwater contaminant levels would continue to exceed drinking water standards.

B. Primary Balancing Criteria

Once an alternative satisfies the threshold criteria, five primary balancing criteria are used to evaluate other aspects of remedial alternatives.

TABLE 10
SUMMARY OF GROUNDWATER ALTERNATIVES DETAILED ANALYSIS

Criteria	G-1: No Action	G-2: Extraction Along I-5, Air Stripping, and Discharge	G-3: Combined Extraction Along I-5 and near Source Areas, Air Stripping, and Discharge
Overall Protection of Human Health and Environment	Low	Medium	High
Compliance with ARARs	Low	High	High
Long-Term Effectiveness and Permanence	Low	High	High
Reduction of Toxicity, Mobility, and Volume	Low	Medium	High
Short-Term Effectiveness	N/A[1/]	Medium	High
Implementability	N/A[1/]	Medium	Medium
State Acceptance	Low	Medium	High
Community Acceptance	Low	Medium	High
Capital Cost	0	$2,654,000	$4,014,000
Operating Costs	$32,240/yr[2/] $16,120/yr[3/]	$354,000[4/]	$517,000[4/]
Net Present Worth (i=10%, n=30 yrs)	$180,000	$6,171,000[5/ 6/]	$9,068,000[5/]
Net Present Worth (i=4%, n=30 yrs)	$309,000	$9,084,000[5/ 7/]	$13,263,000[5/]

1/ N/A=not applicable, assumes no remedial action.
2/ Operating cost for first 2 years.
3/ Operating cost for remaining 28 years.
4/ Cost not including monitoring cost.
5/ Cost including monitoring cost.
6/ Net Present Worth (i=10%, n=50 years) = $6,352,000
7/ Net Present Worth (i=4%, n=50 years) = $10,636,000

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3. Long-term Effectiveness and Permanence. This criteria refers to the ability of a remedial alternative to maintain reliable protection of human health and the environment once remediation goals have been achieved.

Both remedial alternatives 2 and 3 are expected to remediate the groundwater to MCLs. They should maintain reliable protection of human health and the environment once MCLs are met.

Both remedial alternatives provide treatment, but only with the proper operation and maintenance of the extraction/treatment system. In addition, a groundwater monitoring system must be implemented to ensure that remediation goals have been achieved.

The no action alternative is not effective because remediation of the aquifer will not be achieved.

4. Reduction of Toxicity, Mobility, or Volume. This criteria refers to the anticipated performance of the treatment technologies a remedial alternative may employ.

Alternatives 2 and 3 will reduce the volume of the contaminants in the groundwater, and the horizontal and vertical movement of the contaminants. Both alternatives will reduce the concentration of the contaminants to drinking water standards (MCLs). The movement of the contaminants will be controlled upgradient and downgradient of the extraction wells by the zone of influence created by the pumping drawdown action.

Alternative 2 requires a longer period of time (50 years) to achieve a reduction in movement, and volume of the contaminants. Also, since alternative 2 requires more time for remediation, it may allow the contaminant to migrate to the lower aquifers, thus exacerbating the extent of contamination. Alternative 3 takes less time (30 years) and also expeditiously addresses the areas of highest contamination both by additional extraction and treatment in those areas and by flushing the secondary sources in the groundwater.

The no action remedial alternative does not reduce the toxicity, movement, or volume of the contaminants in the groundwater.

5. Short-term effectiveness. This criteria refers to the period of time needed to achieve protection and any adverse impacts on human health and the environment that may be posed during the construction and implementation period until cleanup goals are achieved.

Alternatives 2 and 3 will require approximately six months to construct. Initially, short-term impacts of these alternatives occur during construction. The potential for worker exposure is highest during installation of the groundwater extraction wells and during operation and maintenance of the treatment system. Appropriate health and safety regulations would be implemented (e.g., air monitoring, use of personal protective equipment) during remedial action to provide protection to workers.

There are no short-term environmental impacts during construction of alternatives 2 and 3 that cannot be readily controlled. For example, groundwater from well development will be analyzed for compliance with regulatory requirements prior to discharge or disposal.

This criteria also addresses effectiveness during remediation until cleanup goals are achieved. Alternative 3 has less short-term impact on human health and the environment during remediation because remediation is completed significantly faster than alternative 2. Alternative 2 increases the short-term exposure to contaminated groundwater and emissions from the air strippers by approximately 20 years.

The no action alternative does not include construction or treatment of groundwater and therefore, the risk to workers from these activities would not be present. However, potential exposure to contaminated groundwater would continue indefinitely without remediation of the aquifer.

6. Implementability. This criteria refers to the technical and administrative feasibility of a remedial

alternative, including the availability of goods and services needed to implement the selected remedy.

Alternatives 2 and 3 are designed such that minimal difficulties are expected during implementation. The extraction/treatment system must satisfy groundwater withdrawal, treatment plant emission, and discharge requirements. Air stripping of VOC-contaminated groundwater is a proven and widely-available technology.

The no action alternative requires no implementation other than ongoing monitoring.

7. Cost. This criteria refers the cost of implementing a remedial alternative, including operation and maintenance costs.

The no action alternative includes only the cost of operating the monitoring system. The 30-year present worth cost (assuming i = 10%) for no action is $180,000. This cost does not reflect the fact that monitoring would continue for an indefinite period of time.

Alternative 2 has lower capital costs than alternative 3 because it uses only one treatment system downgradient of the Logistics Center. The 30-year present worth cost for capital and operation/maintenance costs (assuming i = 10%) is $6,171,000. The 50-year present worth cost (assuming i = 10%) is $6,352,000.

Alternative 3 has higher capital costs than alternative 2 because it uses an additional treatment system to extract and treat the groundwater. The 30-year present worth for capital and operation/maintenance costs (assuming i = 10%) is $9,068,000.

C. Modifying Criteria

Modifying criteria are used in the final evaluation of the remedial alternatives.

8. State Acceptance. This criteria refers to whether the state agrees with the preferred remedial alternative.

The Washington State Department of Ecology (Ecology) concurs with the selection of the preferred remedial alternative. Ecology has been involved with the development and review of the Remedial Investigation/Feasibility Study, the Proposed Plan, and the Record of Decision.

9. Community Acceptance. This criteria refers to the public support of a given remedial alternative.

The results of the public comment period and the discussion during the public meeting on June 28, 1990, indicate that the residents of surrounding communities support the preferred remedial alternative. Community response to the remedial alternatives is presented in the Responsiveness Summary, which addresses comments received during the public comment period.

X. THE SELECTED REMEDY

The selected remedy is Alternative 3 - Extract and Treat Downgradient of the Logistics Center and Near Source Areas.

The selected remedy for the Logistics Center operable unit addresses the principal threats posed by the site by treating the groundwater and by flushing secondary source residual contamination. The remedy is designed to reduce exposure to the contaminated groundwater and to remediate the groundwater to levels that are protective of human health and the environment.

A. Major Components of the Selected Remedy

- Install groundwater extraction wells capable of capturing the groundwater contaminant plume in the unconfined aquifer.

- Install on-site groundwater treatment facilities to remove contaminants from the collected groundwater.

- To expedite groundwater remediation, install groundwater extraction wells near areas of highest concentration of contaminants and discharge treated groundwater upgradient of these extraction wells to facilitate flushing secondary sources from the groundwater.

- Monitor the groundwater contaminant plume and the extraction/treatment system during groundwater remediation activities to ensure that both groundwater and surface water remediation goals are achieved.

- Implement administrative and institutional controls that supplement engineering controls and minimize exposure to releases of hazardous substances during remediation.

- Investigate the lower aquifer(s) to determine the presence of contamination and to evaluate the extent of contamination, if necessary. If contamination is found, a groundwater extraction system will be installed which is capable of capturing the contaminant plume with subsequent treatment of the extracted groundwater in the on-site treatment facility. The remediation goals specified for the unconfined aquifer will also apply to any contaminated lower aquifers.

- Perform confirmation soil sampling to ensure that all remaining sources of soil contamination have been identified and characterized.

Based on information obtained during the remedial investigation and on an analysis of the remedial alternatives, the Army, EPA and the State of Washington believe that the selected remedy will achieve this goal. It may become apparent, during implementation or operation of the groundwater extraction system and its modification that contamination levels have ceased to decline over some portion of the plume and are remaining constant at levels higher than the remediation goal. In such a case, the system performance standards and/or the remedy may be reevaluated.

The selected remedy will include groundwater extraction for an estimated period of 30 years, during which the system's performance will be carefully monitored on a regular basis and adjusted as warranted by the performance data collected during operation. Modifications may include:

a. discontinuing pumping at the individual wells where cleanup goals have been attained;

b. alternating pumping at wells to eliminate stagnation points;

c. pulse pumping to allow aquifer equilibration and to allow adsorbed contaminants to partition into groundwater; and

d. installing additional extraction wells to facilitate or accelerate cleanup of the contaminant plume.

It may become apparent during design, implementation, or operation of the effluent discharge system that the system is not effective. For example, the discharge piping may clog because of the natural water chemistry or the disturbed soils may prevent effective infiltration. In such a case, the discharge system may be reevaluated. If necessary, other alternatives for effluent discharge would be considered (e.g., discharge to surface water or to publicly-owned treatment works). Requirements for effluent discharge must then satisfy the provisions of the National Pollutant Discharge Elimination System (40 CFR Parts 121-125).

B. Remediation Goals

The risk assessment concluded that contamination originating from the Logistics Center presents a threat

to human health and the environment. Existing conditions at the site pose a threat predominantly from ingestion and vapor inhalation exposure to VOC-contaminated groundwater.

The goal of this remedial action is to restore groundwater to its beneficial use, which is, at this site, a drinking water source. The groundwater will be restored to levels consistent with state and Federal ARARs which will result in a cumulative excess cancer risk not to exceed 10^{-4}. Remediation levels will be attained throughout the contaminated plume.

Remediation goals were established for chemicals with levels that either: 1) exceed an ARAR; or 2) are not protective of public health or the environment. MCL/MCLGs are exceeded for three compounds: TCE, DCE, and PCE. Total risks for arsenic (As), thallium, TCE, PCE, and vinyl chloride exceeded a 10^{-6} probability for carcinogenic risk and/or a Hazard Index greater than 0.5 for noncarcinogenic risk.

The baseline risks for thallium and vinyl chloride were calculated using one half of the detection limit (per RAGS guidance) for each compound. For the future off-site resident scenario, this corresponds to an excess cancer risk of 4.5×10^{-4} for vinyl chloride and a Hazard Index of 1.5 for thallium. Remediation goals for these compounds were not established because: 1) there is no history of use or disposal of thallium or vinyl chloride; and 2) neither compound was detected in any well during groundwater sampling. Because vinyl chloride is a degradation product of TCE under anaerobic conditions, the Army will include vinyl chloride analysis in the ongoing groundwater monitoring with subsequent air stripping treatment, if necessary.

The total baseline cancer risk for arsenic in soil and groundwater is estimated to be 2×10^{-4}. If this baseline risk for arsenic is added to the combined risk at remediation goals (Table 11), the total risk is then estimated to be 2.8×10^{-4}. It is not clear whether groundwater concentrations from downgradient wells represent a significant difference of arsenic levels in upgradient wells, nor whether the arsenic is natural or anthropogenic in nature.

Remediation of arsenic at the Logistics Center is not included in the selected remedy for the following reasons:

A. The upgradient wells: 1) were installed at varying depths within the hydrogeologic units; 2) were sampled during different sampling events; and 3) samples were analyzed by different laboratories. These differences may explain the range of arsenic upgradient groundwater concentrations of from less than 5 ug/l to 8 ug/l. Due to analytical measurement uncertainty, it is not clear whether groundwater concentrations from downgradient wells represent a statistically significant difference from upgradient wells.

B. Levels of arsenic in groundwater are highly variable in Western Washington. Although the sources are not known, arsenic has been found in a variety of deposits ranging from glacial drift to igneous bedrock. In Pierce County, Washington, elevated arsenic levels have been found in glacialfluvial deposits composed chiefly of sands and gravels. Naturally occurring arsenic is found in arsenopyrite and other arsenic-rich rocks, which are widespread in Washington, as evidenced by mining activities in at least eleven Washington counties.

C. There is no record of current or past uses of arsenic at the Logistics Center.

The concentrations of lead in upgradient wells range from 4.4 to 9.6 ug/l, and in downgradient wells from 2.6 to 28.0 ug/l. As with arsenic, it is not clear whether there is a statistically significant difference in the upgradient and downgradient wells, nor whether these concentrations are due to natural or anthropogenic (man-made) sources. The Battery Acid Pit in the North Uses Area was studied as a potential source of soil and groundwater contamination. Lead contamination in groundwater or soil does not appear to be occurring based on the current understanding of the site. As stated previously, the Army will be performing confirmation soil sampling in all potential source areas within the Logistics Center and will continue to monitor groundwater as part of RD/RA (remedial design/remedial action). Levels found during these sampling events will be compared to current EPA guideline levels for lead in groundwater (15 ug/l) and lead in soils (500 to 1000 mg/kg). If, based on new information, it is

TABLE 11. COMBINED RISK AT REMEDIATION GOALS

	REMEDIATION GOALS (RG)			COMBINED RISK AT RG 1/, 2/, 3/					
				ONPOST RESIDENT		OFFPOST RESIDENT		ONPOST WORKER	
	Groundwater (ug/l)	Surface Water (ug/l)	Soil (mg/kg)	Cancer Risk	Hazard Index	Cancer Risk	Hazard Index	Cancer Risk	Hazard Index
BARIUM					2.4E-02		2.3E-02		1.9E-02
CADMIUM				6.7E-10	2.6E-02	6.1E-11	2.2E-02	2.3E-10	2.0E-02
CHROMIUM				3.8E-08	1.5E-01	3.5E-09	1.5E-01	1.3E-08	1.2E-01
MANGANESE					4.3E-01		4.3E-01		3.4E-01
MERCURY					4.3E-02		4.3E-02		3.4E-02
NICKEL				1.9E-09	1.1E-01	1.8E-10	1.1E-01	6.8E-10	8.6E-02
THALLIUM									
VANADIUM					4.1E-03		1.8E-08		2.6E-03
ZINC					2.3E-02		2.3E-02		1.8E-02
TRICHLOROETHYLENE	5	80		1.3E-05	8.1E-02	6.3E-06	2.4E-02	3.8E-06	4.6E-02
cis 1,2 DICHLOROETHYLENE	70				9.4E-02		7.6E-02		6.9E-02
TOLUENE					3.9E-05		1.7E-08		2.4E-05
ETHYL BENZENE					7.8E-05		1.2E-08		4.8E-05
TOTAL XYLENES					3.5E-05		2.3E-07		2.2E-05
TETRACHLOROETHYLENE	5			4.1E-05	1.2E-02	4.0E-05	1.1E-02	1.2E-05	9.1E-03
1,1,1 TRICHLOROETHANE					1.7E-03		1.7E-03		8.0E-04
TOTALS				5.4E-05	1.0E+00	4.6E-05	9.1E-01	1.6E-05	7.7E-01

1\ Total risk is calculated by combining risk across all exposure pathways and media.

2\ The Hazard Index is calculated by adding noncarcinogenic risks for all chemicals without grouping by similar toxic endpoint or mechanism.

3\ Does not include risks from vinyl chloride or thallium which were not detected in groundwater or soil. Risks from arsenic exposure are also not included per discussion in the text.

determined that soil at the Logistics Center is not within levels that are protective of human health or the environment, the need for treatment will be reevaluated.

For surface water, the levels of TCE found do not exceed the AWQC for the designated uses of each water body. A remediation goal for TCE of 80 ug/l (aquatic organisms only) was established due to the potential for future increases in surface water concentrations from groundwater contamination. The selected remedy is expected to remedy the flow of contaminated groundwater into nearby creeks or lakes. No AWQC have been developed for cis 1, 2 - DCE.

Table 11 summarizes the remediation goals and presents the combined risk for all pathways and media for the on-post resident, the off-post resident, the on-post worker.

XI. THE STATUTORY DETERMINATIONS

The selected remedy meets statutory requirements of Section 121 of CERCLA, as amended by SARA, and to the extent practicable, the National Contingency Plan. The evaluation criteria are discussed below.

A. Protection of Human Health and the Environment

The selected remedy protects human health and the environment through extraction and treatment of the VOC-contaminated groundwater. The contaminants will be permanently removed from the groundwater by air stripping. The volatile dissolved gases will be transferred to the air stream for treatment in accordance with applicable emissions regulations.

Extraction of the VOC-contaminated groundwater also will eliminate the threat of exposure to the most mobile contaminants from ingestion or inhalation of contaminated groundwater. A baseline risk for the off-post residential scenario associated with these exposure pathways is estimated at 3.3×10^{-3} for carcinogenic risk with a HI = 9.7 for noncarcinogenic risks. By extracting the contaminated groundwater and treating it by air stripping, the cancer risk will be reduced to 5×10^{-5} and the HI will decrease to 0.91.

As part of the FS, computer dispersion modeling using the ISCLT method was used to determine the worst-case annual TCE concentration of 0.060 ug/m^3 downwind of the air stripping towers. This airborne concentration corresponds to a cancer risk of 3.7×10^{-7} and a Hazard Index of 1.5×10^{-6}. These levels are within the range of acceptable exposure levels of 10^{-4} and 10^{-6} and the Hazard Index does not exceed one. The need for emission controls will also be evaluated during design in compliance with state ARARs. Therefore, no short-term threats or adverse cross-media impacts will result from implementing the selected remedy.

B. Attainment of Applicable or Relevant and Appropriate Requirements of Environmental Laws

The selected remedy of groundwater extraction, on-site treatment, and passive discharge of the treated groundwater will comply with all applicable or relevant and appropriate requirements (ARARs) of Federal, as well as more stringent, promulgated State environmental and public health laws.

1. Applicable or Relevant and Appropriate Requirements (ARARs)

Both groundwater extraction/treatment alternatives will comply with all action-, chemical-, and location specific ARARs. The ARARs are listed below.

Action-Specific

- State of Washington Hazardous Waste Management Act (Chapter 70.105D RCW) requirements for dangerous waste and extremely hazardous waste as codified in Chapter 173-303 WAC.

- State of Washington Hazardous Waste Cleanup--Model Toxics Control Act (Chapter 70.105D RCW) requirements for the identification, investigation, and clean up of hazardous waste sites are being developed in two phases. Phase I, which defines the administrative process for identifying, investigating, and cleaning up hazardous waste sites, is applicable. All cleanup actions shall use permanent solutions to the maximum extent practicable.

- Substantive water resource antidegradation fundamentals of the State of Washington Pollution Control Act (Chapter 90.48 RCW) and Water Resources Act of 1971 (Chapter 90.54 RCW).

- Requirements of the State of Washington for water well construction as set forth in Chapter 18.104 RCW (Water Well Construction) and codified in Chapter 173-160 WAC (Minimum Standards for Construction and Maintenance of Wells).

- State of Washington requirements (Chapter 173-154 WAC) for the management of groundwater in a manner that protects, to the extent practicable, the upper aquifers of multiple aquifer systems from depletions, excessive water level declines or reductions in water quality.

- Water Pollution Control Act (Chapter 90.48 RCW), Pollution Disclosure Act of 1971 (Chapter 90.52 RCW), and Water Resources Act of 1971 (Chapter 90.54 RCW) require the use of all known, available, and reasonable methods (AKARTs) of treatment prior to discharge to groundwater.

- Requirements of the Clean Water Act section 402 (40 CFR Parts 121-125) for effluent discharge would be applicable if it is necessary to modify or use an alternate effluent discharge system.

- Requirements of the State Waste Discharge Permit Program (Chapter 173-216 WAC) for discharge of waste materials into groundwater.

- State of Washington requirements for hazardous waste operations conducted at uncontrolled hazardous waste sites as set forth in WAC 296-62 Part P (Hazardous Waste Operations and Emergency Response).

Chemical-Specific

Groundwater extraction/treatment activities will meet the following chemical-specific ARARs:

- Federal requirements of the Safe Drinking Water Act (40 USC 300) for groundwater used as drinking water set forth in 40 CFR 141. Specifies maximum contaminant levels (MCLs) for public drinking water.

- Requirements for land disposal of RCRA hazardous wastes as established in 40 CFR 261, 264, and 268 Subpart D.

> The principal wastes (i.e., TCE and DCE) are RCRA listed spent halogenated solvents (F001). Because the groundwater is contaminated by RCRA hazardous wastes, it must be managed as a hazardous waste until it no longer contains the hazardous wastes. An air stripper will be utilized to treat the contaminated groundwater such that the concentration of the hazardous wastes will be below health based levels (i.e., less than MCLs or MCLGs). Consequently, the groundwater will no longer contain hazardous wastes, and thus would not need to be managed as a hazardous waste.

- Water Pollution Control Act (Chapter 90.48 RCW), Pollution Disclosure Act of 1971 (Chapter 90.52 RCW), and Water Resources Act of 1971 (Chapter 90.54 RCW) require the use of all known, available, and reasonable technologies (AKARTs) for controlling discharges to groundwater.

- Ambient concentrations of toxic air contaminants in the Puget Sound region are regulated by the Puget Sound Air Pollution Control Agency (PSAPCA) pursuant to the State of Washington Clean Air Act (Chapter 70.94 RCW) and Implementation of Regulations for Air Contaminant Sources (Chapter 173-403 WAC).

The Best Available Control Technology (BACT) will be required for sources of toxic air contaminants to minimize emissions. The ambient impact of emissions of toxic air contaminants from new sources will be evaluated against Acceptable Source Impact Levels (ASILs) adopted by PSAPCA. Toxic air contaminants are those air contaminants listed in Appendix A of PSAPCA Regulation III or listed in Subpart D, 40 CFR 372. The ASIL for TCE is 0.8 ug/m^3 and the ASIL for DCE is 2630.7 ug/m^3.

Location-Specific

Groundwater extraction/treatment activities will meet the following location-specific ARARs:

- State of Washington Hazardous Waste Management Act (Chapter 70.105D RCW) requirements for dangerous waste and extremely hazardous waste as codified in Chapter 173-303 WAC.

- State of Washington Hazardous Waste Cleanup--Model Toxics Control Act (Chapter 70.105D RCW) requirements for the identification, investigation, and clean up of hazardous waste sites are being developed in two phases. Phase I, which defines the administrative process for identifying, investigating, and cleaning up hazardous waste sites, is applicable. All cleanup actions shall use permanent solutions to the maximum extent practicable.

2. Information To-Be-Considered (TBC)

The following TBCs will be used as guidelines when implementing the selected remedy:

- A screening evaluation of any source may be performed in accordance with PSAPCA's Guidelines for Evaluating Sources of Toxic Air Contaminants (adopted August 9, 1990) to determine if the toxic air contaminant emissions from the source would result in the exceedance of an ASIL contained in Appendix A of PSAPCA Regulation III.

- OSWER Directive #9355.4-02 entitled "Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites", dated September 7, 1989 sets forth an interim soil cleanup level for total lead at 500 to 1000 mg/kg.

- Memorandum re: "Cleanup Level for Lead in Groundwater: from H. Longest, OERR and B. Diamond, OWPE to P. Tobin, Region IV Waste Management Division recommends a final cleanup level for lead in groundwater usable for drinking water which will meet the CERCLA requirement of protectiveness of human health and the environment.

C. Cost Effectiveness

The selected remedy is cost-effective because it has been determined to provide overall effectiveness proportionate to its costs and duration for remediation of the contaminated groundwater. Although the 30-year present worth of $9,068,000 for the selected remedy is higher than Alternative 2, the benefits of an additional extraction/treatment system near the areas of highest groundwater contamination include: 1) a 20-year decrease in potential exposure duration due to contaminated groundwater and air emissions; and 2) a reduction in the lateral and vertical migration of the contaminant plume both downgradient of the Logistics Center and near the areas of highest groundwater contamination.

D. Use of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable

The Army, the State of Washington, and EPA have determined that the selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be used in a cost-effective manner for the Logistics Center site. The risk from the groundwater contamination is permanently reduced through treatment to acceptable exposure levels without transferring the risk to another media (e.g., air). The selected remedy provides the best balance of tradeoffs in terms of long-

term effectiveness and permanence; reduction in toxicity, mobility, or volume achieved through treatment; short-term effectiveness; implementability; and cost.
Although both groundwater extraction and treatment remedial alternatives are protective of human health and the environment, comply with ARARs, and will achieve reduction of risks, there is a significant difference in the time required to achieve remediation goals. Alternative 2 requires approximately 50 years to remediate the groundwater, whereas, Alternative 3 requires approximately 30 years.

E. Preference for Treatment as Principal Element

By treating the VOC-contaminated groundwater in on-site treatment facilities, the selected remedy addresses the principal threat of future ingestion/inhalation of contaminated groundwater posed by the Logistics Center site through the use of treatment technologies. Therefore, the statutory preference for remedies that employ treatment as a principal element is achieved.

RESPONSIVENESS SUMMARY
FORT LEWIS LOGISTICS CENTER

The public comment period was held from June 5 - July 19, 1990. No written comments were received. The Army held a public meeting in Tillicum on June 28, 1990 to explain the proposed plan and solicit public comments. Attached is the portion of the transcript that covered the public comment period held during the public meeting. This summary is a response to questions raised during the public meeting.

1. Is the contaminant a carcinogen? What kind of cancer does it cause?

The primary contaminants found were trichloroethylene (TCE) and cis 1,2 - dichloroethylene (DCE). The United States Environmental Protection Agency (EPA) has classified TCE as a probable human carcinogen, which means it has been shown to cause cancer in animal species. However, evidence from epidemiological studies is inadequate to conclude whether TCE does or does not cause cancer in humans. In mouse and rat studies, long-term inhalation exposure has caused lung, liver, and testicular tumors, as well as, leukemia. Long term ingestion exposure has produced liver and kidney tumors.

The EPA has not determined whether DCE can cause cancer in humans or animals since studies to make this determination have not been conducted. However, adverse effects to the liver and kidney have been observed in rat studies.

2. How fast is the groundwater moving?

The range of groundwater velocity (speed of movement) in the shallow aquifer beneath the Logistics Center varies with the permeability of the various parts of the aquifer. Groundwater movement was measured in monitoring wells at the Logistics Center between 0.03 and 26 feet per day, with an average velocity of 1.5 feet per day.

3. How much is the contamination expanding?

The movement of TCE in sand and gravel aquifers with low organic carbon contents, such as aquifers beneath the Logistics Center, is approximately one-half the average groundwater velocity of 1.5 feet per day. Consequently, contamination movement would be approximately 0.75 feet per day. Also, TCE concentration further decreases approximately one-half of 0.75 for every mile the plume moves because of dispersion (the lateral spread of contaminants as they move with the groundwater) and volatilization (evaporation) into gas.

4. What is the expected date that it will hit and contaminate American Lake?

The Army sampled American Lake as part of the Logistics Center investigation. The sampling showed that there are low levels of TCE and DCE in the lake, but the levels do not exceed drinking water standards. The Army will continue to sample American Lake as part of a long term monitoring program.

5. Could the movement be isolated and cut off so that it does not hit and contaminate American Lake?

The groundwater alternative that has been selected consists of a series of wells within and near the Logistics Center. These wells together with the treatment system should stop the plume from moving towards American Lake. As mentioned in question 4, the Army has not found elevated levels of contaminants in American Lake, but will include it in the monitoring program.

PUBLIC COMMENT SESSION

MR. CAGLE: What I'd like to ask is, if you have comments on the plan, on the process, on the problem, if you would like to stand up and talk about them publicly, would you please state your name and your address for the record so that we can get a response back to you.

If you don't want to stand, you can put your question or your comment on the index cards. Again, please put your name and address on it so we can work it for the record and get back to you with a response.

Do we have any public comments at this point? That's why we are here.

(b) (6) What is the basic hazard, that we are facing as far as this material is concerned, health-wise?

MR. CAGLE: All right, sir, your name and address on that?

(b) (6) I'm (b) (6)

(b) (6)

MR. CAGLE: Do we need to address any of these at this point?

MS. DURBIN: I don't really know what -- Other than --

MR. LIVERMAN: Well, sir, were you thinking perhaps that water or soil --

(b) (6) Is it a carcinogen?

MR. LIVERMAN: -- or what one's susceptibility might be?

TCE is a known carcinogen, a probable carcinogen.

(b) (6): What kind of cancer does it cause; any idea?

MR. LIVERMAN: I'm not sure.

(b) (6) Well, I was just wondering if I got mine from the water.

MR. LIVERMAN: I'll pass on that.

MS. DURBIN: We'll definitely address it, though. I will definitely put that in a written response. I'll find out for you.

(b) (6) Can you do that?

MS. DURBIN: Yes. I'm not sure.

MR. CAGLE: All right, sir.

Any other comments about the plan, about the problems, about the proposals?

MS. DURBIN: And also if anybody that asked questions in the informal portion, if you'd like to state your name and phone number and address for the record, we can get a response back to you. If you

wanted something additional or whatever, we could do that too.

THE AUDIENCE: (No response.)

MR. CAGLE: No comments. Keep it open for a few minutes.

MS. DURBIN: And again, any written comments that you have, if you could put them on the front table, we could collect them there.

Also, the "Public Comment Period" does continue. It will continue to be open until the 19th of July and we can take your public comments at any time.

UNIDENTIFIED SPEAKER: That can be mailed to this address that you have here?

MS. DURBIN: Exactly. That's exactly right.

MR. CAGLE: And you don't have to confine it to the size of an index card either.

MS. DURBIN: No, no. And any comment that you make can be not only on our Proposed Cleanup Plan, but it can also be on the whole investigation that we did. Any comments that you'd like to make on it, please do.

MR. CAGLE: Are there any thoughts that you have of areas that might not have been considered in the review process?

Yes, sir.

(b) (6) Are you interested in whether we are interested -- whether we want the 50-year plan or the 30-year plan, or what sort of plan?

MR. CAGLE: That could be part of your comment, yes, sir.

(b) (6) My name is (b) (6) I live at (b) (6)

I would be very much in favor of the 30-year plan rather than the 50-year plan. Let's get this thing cleaned up.

Also, at the same time I'm wondering, just how fast are these fluids moving? How much is this expanding? How much time do we have to clean it up?

MR. LIVERMAN: Well, the groundwater beneath the Logistics Center is estimated to travel perhaps one and a half feet per day. That estimate ranges to as much as seven feet per day.

Of course, that would be influenced by seasonal variations, such as during periods of high rainfall, it is entirely possible that it may run more rapidly than it would otherwise during the drought season.

So with that thought in mind of perhaps one and a half feet per day, that would give you some estimate as to how long it would take to travel.

(b) (6) The distance that you would

indicate on there, the northern part of Tillicum, is expanding, we'll say a foot and a half to seven foot a day, and heading towards American Lake?

MR. LIVERMAN: Well, sir, it is not expanding perhaps in the sense of -- It is moving towards the lake. And that's not to necessarily suggest that is expanding horizontally beyond the boundaries that are indicated on the map here.

(b) (6) What is the expected date that it will hit and contaminate the lake?

MS. DURBIN: I'm not -- I can't really answer that at this time, but it is definitely something that we can address in the response.

(b) (6) Is this something that could be isolated and cut off and treatment started over there, or is all of your treatment going to be on the base?

MS. DURBIN: One of the things that we are trying to do, as far as looking at treatment, is we try to put the well closest to the source area, the source area being the East Gate Disposal Yard and the Logistics Center itself. It is more effective in that particular area, and that is one of the reasons we looked at that.

(b) (6) But would the source area,

which is far away from the tip in the northern part of Tillicum there draw that contaminants back?

MS. DURBIN: Probably not.

(b) (6) They'd stay there forever then?

MR. HANNA: No. No, sir. It will continue to move toward forward.

The way in which the plan is now conceptually presented is to intercept the groundwater at two locations, that being in close proximity to the East Gate Disposal Yard, and also in close proximity to I-5.

That is not to suggest that two wells here or four wells is the answer. There may be considerably more.

The intent is to extract the groundwater to treat it, and then to allow it to passively recharge back into the groundwater.

In the instance of the East Gate Disposal Yard, at a configuration yet to be designed, it would have the effect of not only flushing the soil, in the sense that you would flush contaminates that may or may not be present in the soil into the groundwater, to the extent that they would be intercepted at the extraction wells and then processed.

At the I-5 location, the intent is to have a series of extraction wells to intercept the plume and to treat the water, and then at a location closer to I-5, allow it to passively recharge the groundwater, and in doing so, push the plume, if you will.

But the plume should not remain stagnant between I-5 and American Lake. It will continue to move. And as a result of having the clean groundwater recharge -- or rather, having the water recharge the contaminated groundwater, that should not only dilute the contamination, which in conjunction with natural rainfall and a percolation of that nature, it should remediate the groundwater to an acceptable level, that being MCL.

(b) (6) Thank-you.

MS. DURBIN: In addition, the type of chemical that we are dealing with is TCE, and it wants to vaporize, it wants to go into the air.

So when it goes toward American Lake, and when it gets there, that is what it tends to do. And that is one of the reasons that we think we're not violating the levels in American Lake.

So, yes, the plume is moving and it will clean. It will flush it out.

MR. CAGLE: Any other comments.

THE AUDIENCE: (No response.)

MR. CAGLE: I thank you. I think this will conclude the session for now. We'll be around for a few minutes to answer individual questions.

I'm sure that if you have any comments, you can go ahead and fill them out on the card and bring them up here, or send them to Kris at the address on the fact sheet.

MS. SCHNEIDER: There are also copies, a summary of the slide show that was given outside and will serve to refresh your memory of what you saw.

MS. DURBIN: Thank you very much for your comments.

MR. CAGLE: And thank you all very much for coming out tonight. We appreciate your interest.

(Meeting concluded at 8:25 p.m.)

(Comment made after meeting and put on record at request of Ms. Durbin:)

(b) (6)

(b) (6)

The question was, what happens to the fumes or whatever that comes up into the air? What does it do to us in our breathing?

MS. DURBIN: What I said is, it will immediately break down into the chemicals that that

is made up of, the chlorine, carbon dioxide, and water, or in a few days the sunlight will help break it down.

END OF ADDITIONAL ON-RECORD COMMENT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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